

Testing Piketty’s Hypothesis on the Drivers of Income Inequality: Evidence from Panel VARs with Heterogeneous Dynamics

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Abstract

Thomas Piketty’s *Capital in the Twenty-First Century* puts forth a logically consistent explanation for changes in income and wealth inequality patterns. However, while rich in data, the book provides no formal empirical testing for its theoretical causal chain. In this paper, I build a set of Panel SVAR models to check if inequality and capital share in the national income move up as the $r - g$ gap grows. Using a sample of 19 advanced economies spanning over 30 years, I find no empirical evidence that dynamics move in the way Piketty suggests. Results are robust to several alternative estimates of $r - g$.

Keywords: Income Inequality, Panel VAR, Factor Income Distribution.

JEL Codes: D33, C12, C33.

1 Introduction

Capital in the Twenty-First Century, Thomas Piketty's *magnum opus*, has been widely praised for aggregating and presenting in a timely and accessible fashion the results of more than a decade of research spearheaded by Piketty and his co-authors. His work is likely to remain influential in the times to come, not only for its databases, which map the (traditionally scarce) information about income inequality but also because it is inspiring many economists to use the estimation techniques he and his co-authors popularized to further our knowledge of these phenomena in different countries.

Piketty's theoretical explanations for changes in inequality patterns are logically consistent. Using a standard neoclassical model, he argues that all other things constant, whenever the difference between the returns on capital (r) and the output growth rate (g) increases, the share of capital in the national income must increase. Furthermore, since capital income tends to be more unequally distributed than labor income, an increase in the capital share would likely lead to increased overall income (and, over time, wealth) inequality. Both of these are plausible relationships. However, while rich in data, *Capital* provides no formal empirical testing for these conjectures. In fact, there is little more than some apparent correlations the reader can eyeball in charts containing very aggregated multi-decennial averages.

The main contribution of this paper is to provide an empirical test of Piketty's hypotheses. For that purpose, I build Panel Structural Vector Autoregressive models to test if inequality and the capital share in the national income increase as the $r - g$ gap grows. I use Pedroni's (Peter Pedroni, 2013) recent Panel VAR technique, which controls for country fixed-effects and allows for full heterogeneity of dynamics across countries, to estimate these relationships in a panel of 19 advanced economies spanning over 30 years. This technique results in a distribution of impulse response functions, permitting a much more robust inference than those that rely on average estimates and assume slopes are homogeneous.

I find no empirical evidence that the dynamics move in the way Piketty suggests. In fact, for at least 75% of the countries examined, inequality responds negatively to $r - g$ shocks, which is in line with previous single-equation estimates by Acemoglu and Robinson (2015). The results also suggest that changes in the savings rate, which Piketty takes as relatively stable over time, are likely to offset most of the impact of $r - g$ shocks on the capital share of the national income. Thus, they provide empirical support to the theoretical model developed by Krusell and Smith (2015), who say Piketty relies on a flawed theory of savings. The conclusions are robust to alternative estimates of $r - g$ and to the exclusion or inclusion of tax rates in the calculation of the real return on capital.

Knowing if Piketty's hypothesis is correct is of crucial importance. Such is the case because the policy solutions designed to counter increasing income inequality trends in advanced economies will need to tackle the underlying causes of inequality. The results presented here show that observed increases in income inequality in advanced economies are largely uncorrelated with changes in $r - g$, which suggests that one needs to look for the causes of inequality (and potential solutions) elsewhere.

This paper outlines Piketty's theoretical model and develops a strategy to test it. First, I present a

simplified description of the basic theoretical relationships Piketty proposes. Then I describe the data and how I constructed some of the variables of interest and explain the methodology of the structural Panel VAR. Afterwards, I present the results (paying special attention to how to interpret heterogeneous dynamics), perform some robustness tests, and try to relate the set of results to the bulk of the literature on income inequality, pointing to potential causes of increasing inequality which are not related to $r - g$. Finally, I conclude by summarizing the most important points of the paper and what they mean for future inequality dynamics.

2 Piketty’s Model: What to Test

Building on a standard growth model, Thomas Piketty (2014) argues that the patterns of wealth and income concentration are defined by the difference in the real return on capital (r) and growth rates (g). Here, I present a very stylized derivation of Piketty’s model and its implications, so as to develop a testing strategy.

Envision a closed economy where national income (Y) is a function of capital (K) and labor (L), $Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}$, where A_t is a time-varying labor augmenting technology, and the final good is produced in competitive markets. Under these assumptions, clearly, an equilibrium implies that $r_t = \frac{\partial Y_t}{\partial K_t} = \alpha Y_t / K_t$, $w_t = \frac{\partial Y_t}{\partial L_t} = (1 - \alpha) Y_t / L_t$. By inverting the first-order condition with respect to capital, Piketty derives what he calls the “first fundamental law of capitalism”:

$$\alpha = \frac{rK}{Y} \quad (1)$$

Furthermore, assume that investment is a constant share s of national income at any period t . Under that assumption, the law of motion of capital is $K_{t+1} = (1 - \delta)K_t + sY_t$. Suppose that A_t grows exogenously at rate $(1 + g)$ and population is constant. Then, one can show that, over the balanced growth path (BGP): $\frac{Y_{t+1}}{Y_t} = \frac{K_{t+1}}{K_t} = \frac{A_{t+1}}{A_t} = (1 + g)$. Using the law of motion for capital, then, along the BGP¹:

$$(1 + g)K_t = (1 - \delta)K_t + sY_t \iff \frac{K_t}{Y_t} = \frac{s}{g + \delta} \quad (2)$$

Substituting (2) into (1) yields what Piketty calls the “second fundamental law of capitalism” —an inverse relationship between the share of capital in the national income and economic growth:

$$\alpha = \frac{rs}{g + \delta} \quad (3)$$

where r denotes the real return on capital along the BGP².

¹Piketty defines all of his variables in *net* terms, such that one should deduct depreciation from income, capital, and the savings rate. But, since both expressions are equivalent in their steady states (Krusell and Smith, 2015), and most standard textbooks use variables in gross terms, it is more expedient to explicitly account for depreciation.

²For instance, a standard model with CRRA preferences, one can use the Euler Equation and find that $r = \frac{1}{\beta} - (1 - \delta)$.

Taking the (net) savings rate as somewhat constant, Piketty and Zucman (2015) argue that the capital share, income inequality, and wealth inequality are rising functions of $r - g$. If Piketty is correct, then one should expect a positive shock to r or a negative shock to g to increase the capital share of national income. Piketty goes on to argue that as the returns on capital are more unequally distributed than labor income, a higher share of capital in the national income would lead to higher income and wealth inequality (Piketty, 2014, ch. 7).

These relationships are empirical propositions and hence empirically testable. The testable hypotheses are that positive changes in $r - g$ lead to positive changes in inequality and capital share. Piketty stresses that these dynamics are long-run and asymptotic, hinting at potential difficulties in capturing them. Still, if the model is correct, deviations around the long-run average should provide some evidence of the underlying relationships.

3 Data and Stylized Facts

In order to analyze the relationship between inequality, capital share and returns on capital to GDP growth differentials, I organize data from multiple sources. Data availability varies by country and the maximum range used in this paper goes from 1980 through 2012. Data on the capital share and share of the top 1% are more reliable for advanced economies. For such reason, the final sample is an unbalanced long panel with annual observations for 19 advanced economies from different continents (see Appendix A for details).

Inequality is proxied by the share of national income held by the top 1%, as reported by the World Top Incomes Database. The choice of such variable is rather obvious since this is Piketty’s measure of choice (as compared to alternative metrics, like the Gini index) to indicate rising inequality in advanced economies in the past decades. The annual capital share in the national income comes from the Penn World Tables.

To derive the second variable of interest —namely, the real return on capital net of real GDP growth—I take yearly averages of nominal long-term sovereign bond yields, calculate the post-tax nominal rates by deducting corporate income taxes and subtract from them annual percent changes in GDP deflators and real GDP growth. The r in $r - g$ is, then:

$$r_{i,t} = [(1 - \tau_{i,t})i_{i,t} - d_{i,t}] \quad (4)$$

where $r_{i,t}$ is the real return on capital, $\tau_{i,t}$ is the corporate income tax rate, $i_{i,t}$ is the nominal long-term sovereign bond yield, and $d_{i,t}$ is the annual percent change in the GDP deflator for country i at period t . GDP deflators and real growth rates are found in the IMF’s World Economic Outlook database. Tax rates come mostly from the OECD’s Tax Database —with the exception of the time series for Singapore, which was constructed independently.

The choice of sovereign bond yields as a proxy for returns on capital is not self-evident. In reality, the aggregate return on capital is a weighted average of returns across a plethora of investments. However,

returns on government bonds are a good proxy for the purposes of this empirical exercise for two reasons. First, Piketty’s narrative centers on worries about a society facing the unmeritocratic rule of rentiers who profit from high returns on capital, which he illustrates by discussing how 19th century élites profited from high returns on government bonds (Piketty, 2014, p. 132). Second, even if the level of return is different for different portfolios, the correlation between sovereign bonds and corporate bonds is historically very high. In fact, between 1996 and 2015, the correlation between prime AAA corporate bonds and U.S. treasuries was nearly perfect ($r = 0.93$); even when considering “junk” BB+ graded corporate bonds the co-movement between sovereigns and corporates was relatively tight ($r = 0.49$).

Thomas Piketty (2016) criticized an earlier version of this paper for the use of interest rates as a proxy for returns on capital. His argument is a sensible one: in modern times, portfolios are very diversified, and the returns on capital for the very wealthy are often higher than returns on government bonds. He referred to his own estimates of the real wealth growth rate of top 1/20 million, based on Forbes Magazine’s billionaires lists, to argue it outpaced overall *per capita* real wealth growth in the 1987-2013 period. It should be noted that there is high uncertainty regarding the quality of Forbes estimates. For instance, Raub, Johnson and Newcomb (2010) found that wealth reported in tax data only corresponds to about half of Forbes’ list. With different assumptions, either number could be closer to true wealth stocks.

More importantly, this argument does not address whether or not interest rates are a good proxy for returns on capital. Level differences notwithstanding, in so far as returns on capital can be reasonably expressed as a linear function of returns on government bonds, the latter are a good proxy for the former.

Data on heterogeneous returns on capital are scarce. Some years ago, the editors of Credit Suisse’s *Global Wealth Databook*, who have been publishing estimates of wealth concentration across countries for several years highlighted that “study of global household wealth is still in its infancy.” (Shorrocks, Davies and Lluberas, 2016). More recently, the *World Inequality Report* recalled that “global wealth data remain opaque,” and many of the estimates they provide come from extrapolations from income inequality data, and/or limited population coverage.

These caveats notwithstanding, the Federal Reserve has recently published its Distribution Financial Accounts. They provide estimates of asset stocks for different ownership brackets going back to 1989. The database uses underlying microdata from the Survey of Consumer Finances. Regressing the 4-quarter net return on assets³ of the Top 1% on 3-mo treasuries yields the following relationship: $\hat{R}_{q,t}^{1\%} = \frac{1.81}{(0.010)} + \frac{1.60}{(0.000)} R_{q,t}^{3mo}$. With 10-year bonds, the relationship with 10-year bonds is $\hat{R}_{q,t}^{1\%} = \frac{2.23}{(0.93)} + \frac{1.30}{(0.003)} R_{q,t}^{10yr}$.

The specific criticism Piketty made regarding the use of sovereign bond yields thus appears to be largely unfounded. However, in recognizing the challenge to find good proxies for the return on capital, I present results with two different proxies for r in the robustness section: short-term interest rates, and implied returns from the national accounts. I also present results ignoring tax rates.

³If $A_{q,t}^{1\%}$ is the asset stock of the Top 1% at quarter q of year t , the 4-quarter net return on assets is: $R_{q,t}^{1\%} = \frac{\sum_{p=0}^3 A_{q-p,t}^{1\%}}{\sum_{p=0}^3 A_{q-p,t-1}^{1\%}} - 1$.

Distributions of capital share and share of the top 1% in the sample show increasing trends, although with some signs of moderation in the late 2000s due to the global financial crisis. The upward trend is observed not only in the medians but also in the evolution of interquartile ranges, as shown in Figure 1.

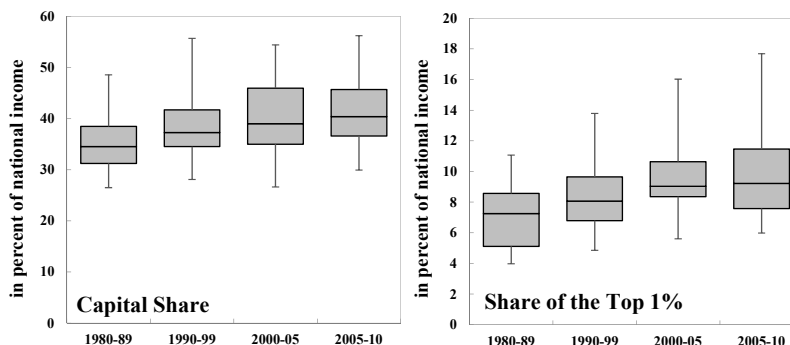


Figure 1: **Distribution of capital share and share of the top 1% over time.** Y-axis in percent, x-axis represents period averages. The sample refers to an unbalanced panel of 19 advanced economies ranging from 1981-2010. Boxplots show interquartile ranges and medians. Whiskers show minimums and maximums.

Basic stylized facts can provide some preliminary insights regarding whether or not the data support Piketty's assertions. Figure 2 plots the contemporaneous correlations between $r - g$ spreads and capital share, and share of the top 1%. Such basic correlations show no evidence of the relationship Piketty poses. Rather, the variables seem largely orthogonal. However, as mentioned before, Piketty's theory is largely about the long-run.

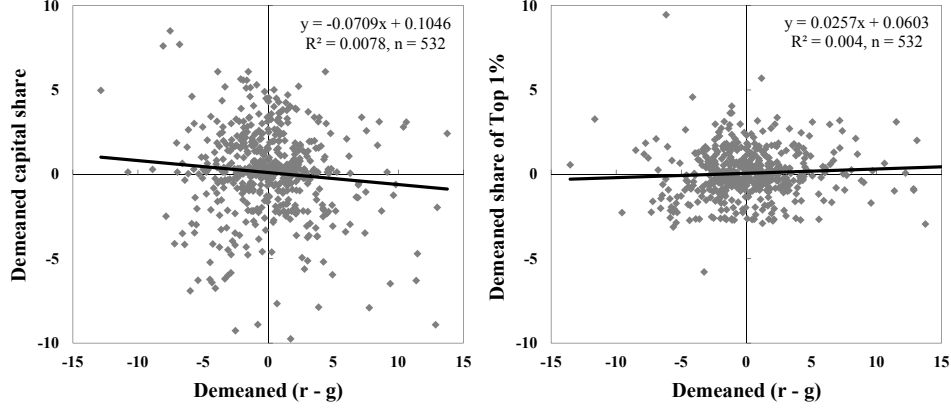


Figure 2: **Contemporaneous correlations between $r - g$ spread and capital share or share of the top 1%, respectively.** The sample refers to an unbalanced panel of 19 advanced economies ranging from 1981-2012. Variables are demeaned to account for time-invariant country-specific characteristics.

If the absence of a positive relationship persists with more refined estimation techniques that capture the dynamics around the long-run trend, this could raise questions about Piketty's assertion that a higher $r - g$ will lead to higher inequality over the coming century. In the next section, I describe an empirical method to test precisely that.

4 Methodology

Following Pedroni (2013), I estimate a structural Panel VAR that accommodates country-fixed effects, allows dynamics to be fully heterogeneous amongst panel members and decomposes dynamics between different responses to *idiosyncratic* and *common* shocks. In that context, for each member $i = [1, \dots, M]'$ of an unbalanced panel, let $y_{i,t}$ be a vector of n endogenous variables with country-specific time dimensions $t = [1, \dots, T_i]'$. To control for individual fixed-effects, I demean the data, resulting in $y_{i,t}^* = y_{i,t} - \bar{y}_i$, where $\bar{y}_i \equiv T_i^{-1} \sum_{t=1}^{T_i} y_{i,t} \forall i$. The baseline model is:

$$B_i y_{i,t}^* = R_i(L) y_{i,t-1}^* + u_{i,t} \quad (5)$$

where $y_{i,t}^*$ is a n -dimensional vector of demeaned stacked endogenous variables, $R_i(L)$ is a polynomial of lagged coefficients [$R_i(L) \equiv (\sum_{j=0}^{J_i} R_j^i L^j)$] with country-specific lag-lengths J_i , R_j^i is a matrix of coefficients, $u_{i,t}$ is a vector of stacked residuals, and B_i is a matrix of contemporaneous coefficients. J_i are selected based on appropriate criteria to assure that residuals approximate white noise.

To allow for heterogeneous dynamics, I first estimate and identify reduced-form VARs for each country i :

$$\begin{aligned}
B_1 y_{1,t}^* &= R_1(L) y_{1,t-1}^* + u_{1,t} \\
&\vdots \\
B_M y_{M,t}^* &= R_M(L) y_{M,t-1}^* + u_{M,t}
\end{aligned} \tag{6}$$

and then estimate another auxiliary VAR to recover *common* dynamics. Common dynamics are captured by averages, across individuals, for each period ($\bar{y}_t^* \equiv M^{-1} \sum_{i=1}^M y_{i,t}^*$):

$$\bar{B} \bar{y}_t^* = \bar{R}(L) \bar{y}_{t-1}^* + \bar{u}_t \tag{7}$$

After transforming the reduced-form residuals in (6) and (7) into their structural equivalents ($e_{i,t} = B_i^{-1} u_{i,t}$ and $\bar{e}_t = \bar{B}^{-1} \bar{u}_t$, respectively), I run nM OLS regressions to decompose the shocks into two terms:

$$\begin{aligned}
e_{1,t} &= \Lambda_1 \bar{e}_t + \tilde{e}_{1,t} \\
&\vdots \\
e_{M,t} &= \Lambda_M \bar{e}_t + \tilde{e}_{M,t}
\end{aligned} \tag{8}$$

where $e_{i,t}$ are *composite shocks*, $\bar{e}_{i,t}$ are *common shocks*, $\tilde{e}_{i,t}$ are *idiosyncratic shocks*, and Λ_i are n -by- n diagonal matrices with country specific loadings (the coefficients from the OLS regressions) denoting the relative importance of common shocks for each country. Note that $\tilde{e}_{i,t}$ vectors are truly idiosyncratic, since they are by construction orthogonal to the shocks derived from the average dynamics shared by all panel members.

Subsequently, I use standard methods described in Lütkepohl (2007) to recover the matrices of composite responses to structural shocks $[A_i(L)]$ for each country, which are shown below in the vector moving average representations of M structural VARs:

$$\begin{aligned}
y_{1,t}^* &= A_1(L) u_{1,t} \\
&\vdots \\
y_{M,t}^* &= A_M(L) u_{M,t}
\end{aligned} \tag{9}$$

and then use the loading matrices estimated in (8) to decompose the composite responses into country-specific responses to common shocks and responses to idiosyncratic shocks:

$$\begin{aligned}
A_1(L) &= \Lambda_1 A_1(L) + (I - \Lambda_1 \Lambda_1') A_1(L) \\
&\vdots \\
A_M(L) &= \Lambda_M A_M(L) + (I - \Lambda_M \Lambda_M') A_M(L)
\end{aligned} \tag{10}$$

Equivalently, $A_i(L) = \bar{A}_i(L) + \tilde{A}_i(L)$, where $\bar{A}_i(L) \equiv \Lambda_i A_i(L)$ and $\tilde{A}_i(L) \equiv (I - \Lambda_i \Lambda_i') A_i(L)$. I then use the cross-sectional distribution of $A_i(L)$, $\bar{A}_i(L)$ and $\tilde{A}_i(L)$ to describe some properties of the collection of impulse response functions calculated, such as their medians, averages and interquartile ranges.

After recovering the point estimates of all the impulse response functions, I calculate standard errors of medians through a re-sampling simulation repeating all the steps above 500 times (see Appendix B for details).

5 Empirical Models and Results

I run three models with the methodology described above:

- In **Model 1**, $y_{i,t} \equiv [p_{i,t}, z_{i,t}]'$, where $z_{i,t}$ is the national income share of the top 1% for country i at period t and $p_{i,t} \equiv (r_{i,t} - g_{i,t})$ is the post-tax return on capital (r) net of real GDP growth (g).
- In **Model 2**, $y_{i,t} \equiv [p_{i,t}, k_{i,t}]'$, where $k_{i,t}$ is the share of capital in national income.
- In **Model 3**, $y_{i,t} \equiv [p_{i,t}, s_{i,t}, k_{i,t}]'$, incorporating the savings rate ($s_{i,t}$).

Note that, since the data are demeaned to control for country-fixed effects, if one takes the rate of depreciation as time-invariant, even if different for each country, it is not necessary to explicitly account for it in the empirical model. Depreciation is treated away once the data are demeaned as $p_{i,t}^* \equiv (r_{i,t} - g_{i,t})^* = (r_{i,t} - g_{i,t} - \delta_i)^*$.

In identifying the Cholesky decomposition, I order $r - g$ first, imposing lower triangular restrictions in the contemporaneous coefficients such that $r - g$ contemporaneously impacts the share of the top 1% and the capital share and $r - g$ responds to shocks to the share of the top 1% and the capital share only with a lag. In the robustness section, I present results with the inverse restrictions.

Pedroni's methodology allows for fully heterogeneous dynamics. This means that the results of the Panel VAR are more than *average* parameters and *average* impulse response functions —as they are in traditional panels, which impose homogeneous parameters. Rather, I have information about several moments of the distributions of impulse responses for each response horizon. With those data, I can then plot averages, medians and interquartile ranges of responses for a given horizon, as shown in Figure 3.

This is a much more informative way of reading results than in traditional panel VAR analyses. For instance, had I calculated average impulse responses from parameters estimated with traditional dynamic panels (e.g., difference or system GMM equations), I would have no way of knowing how many countries in the sample have dynamics that are similar to the average dynamics —as the underlying assumption is that parameters are equal for all countries. Effectively, knowing exactly how many countries in the sample present certain dynamics provides for much more robust inference than simply relying on average estimates. In addition to that, as shown by Pesaran and Smith (1995), if individual dynamics are heterogeneous,

aggregating or pooling slopes can lead to inconsistent estimates, making individual regressions for each group member preferable.

Despite country-specific heterogeneity, the estimated VARs are stable. We observe that by noting that the inverse roots of the characteristic polynomial related to each country-specific matrix of VAR coefficients are within the unit circle. Several of the variables are shares and have bounded support, which rules out the possibility of a unit-root in the traditional sense⁴. Others, such as $r - g$ must have some finite mean for an economic equilibrium to exist.

This means that one-off shocks should be interpreted as temporary and, following any shock, variables are expected to converge back to their means or deterministic trends over the long-run. In line with the outlined theory, one should interpret these as deviations around the long-run BGP.

The results of **Model 1** show that for at least 75% of the countries a 1% positive innovation to $r - g$ leads to an expected decrease in the share of the top 1% (see Figure 3). While the median response is not statistically significant contemporaneously, it is negative and statistically significant in the mid- to long-run (see Figure 4). The responses to common and idiosyncratic shocks have the same (negative) sign and contribute to the effect with about the same response. This decomposition can help one understand how much systemic forces (as, for instance, globalization) could be exacerbating inequality as returns on capital increase (see Figure 5).

⁴Granger (2010) expanded the idea of nonstationarity to bounded variables, terming a stochastic process that behaves as if a $I(1)$ but has at least one bound a limited integration or $LI(1)$ process. Note that for many of the variables I use in the estimation, there are upper and lower bounds, such as capital share or the savings rate, both bounded within $[0, 1]$. In that case, by assumption, those variables cannot be integrated in the traditional sense, but could behave like one away from the bounds.

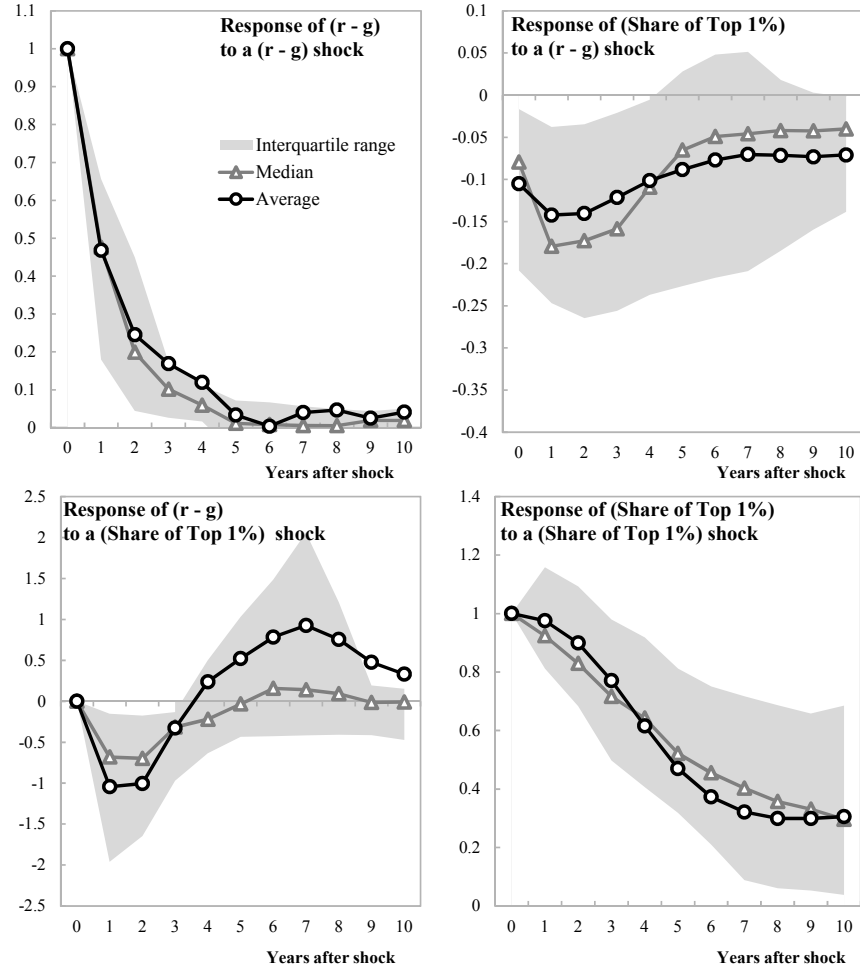


Figure 3: **Model 1: Heterogeneous composite impulse responses across sample.** The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 19 cross-sections.

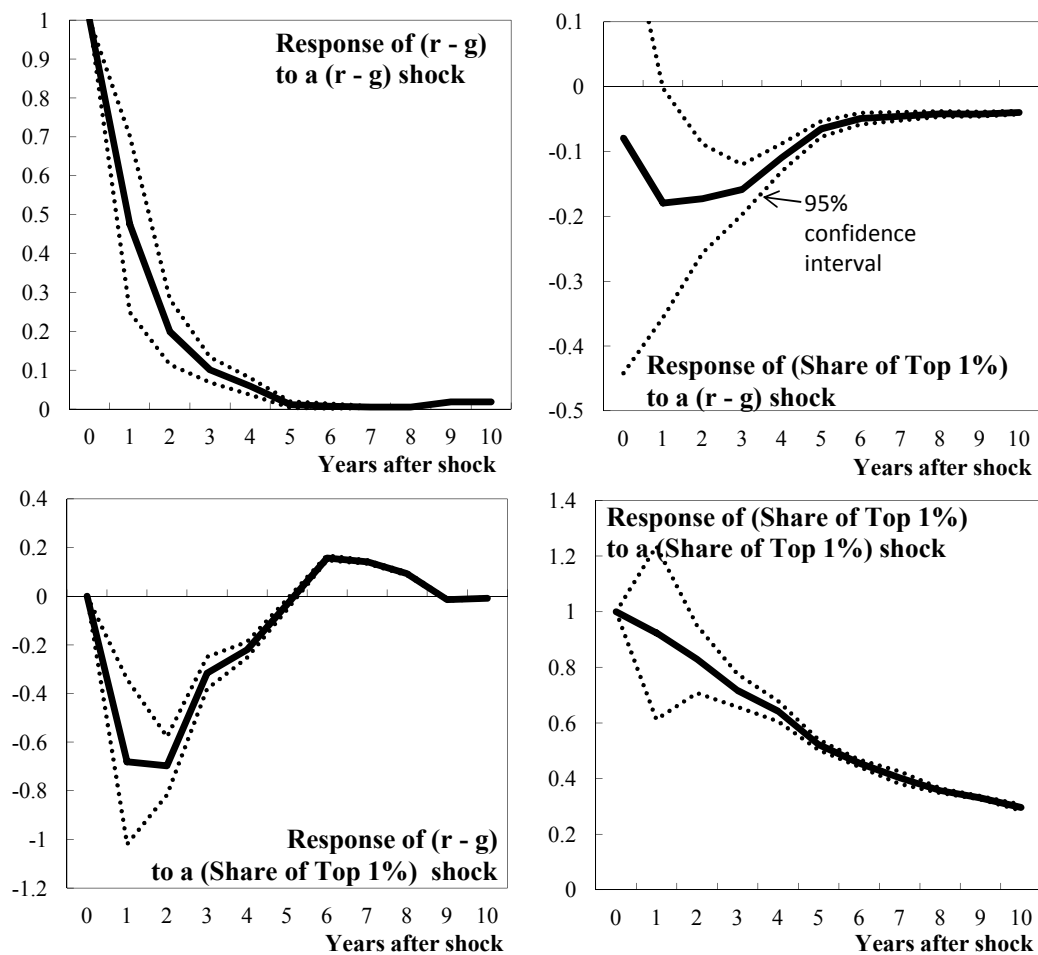


Figure 4: **Model 1: Median composite responses and confidence intervals.** Median response across a heterogeneous distribution of IRFs across 19 countries. Confidence intervals calculated from a resampling simulation with 500 repetitions. Since the distribution might change for each repetition in the simulation exercise, the confidence intervals do not represent the uncertainty around estimates for any particular country, but rather for the median estimate of the whole panel.

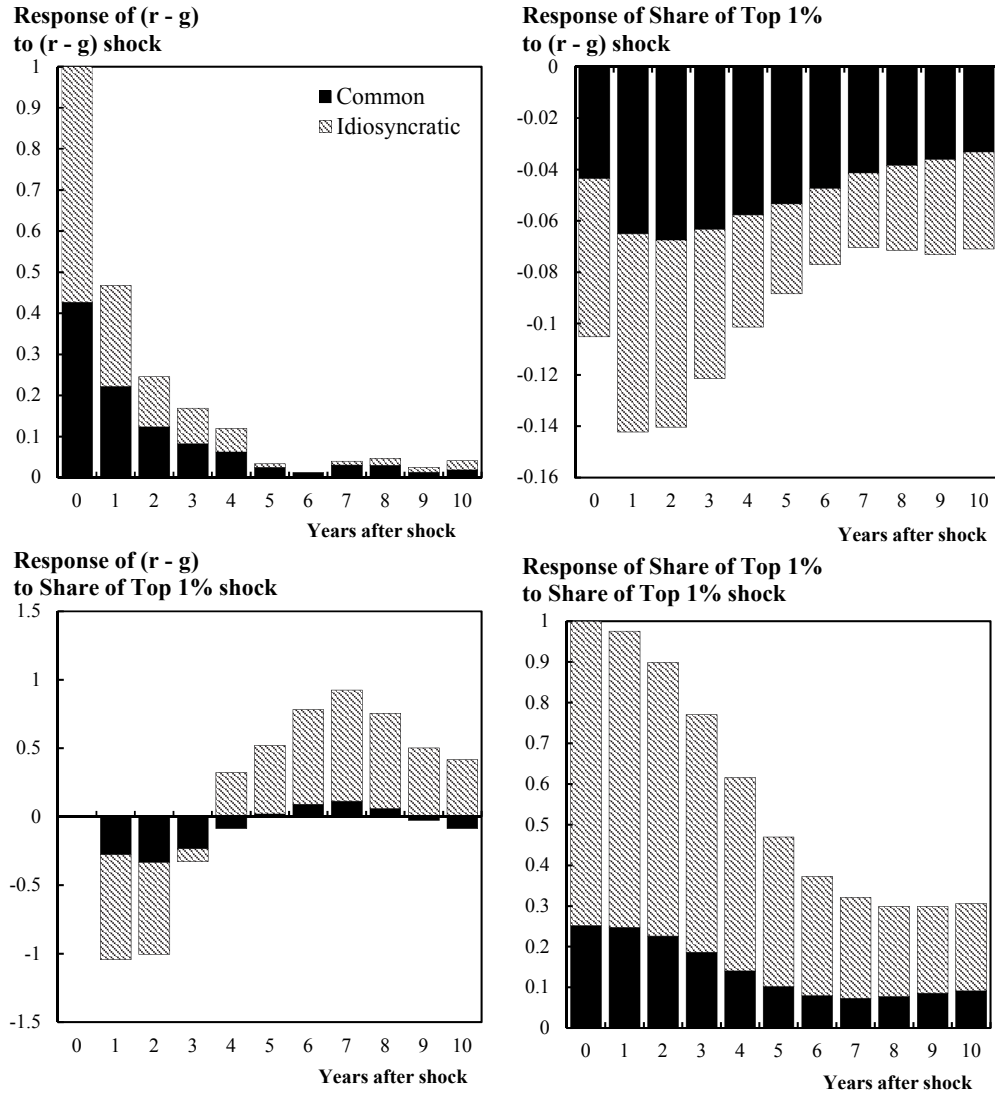


Figure 5: **Model 1: Decomposition of median composite responses.** Median responses can be decomposed into country-specific responses to common shocks and responses to idiosyncratic shocks through the use of loading factors that denote the relative importance of common shocks for each country

One of the advantages of estimating heterogeneous slopes is that one can explore the variability in parameters across the cross-sectional dimension of the panel. One can do that by correlating the response magnitudes of the different countries in the sample with potential covariates. I plot below some bivariate relationships that can provide some intuition on the causes and effects of the existent heterogeneity in responses.

There is a positive correlation between estimates of the intergenerational elasticity of income —which measures the share of a person’s income explained by the parent’s income —and the size of the contemporaneous response of inequality to $r - g$ shocks. This hints at the idea that a higher transmission between $r - g$ and the share of the top 1% leads to a higher observed level of wage and wealth persistence.

Similarly, contemporaneous responses of inequality to $r - g$ shocks are positively correlated with social expenditure as a share of GDP for countries in the sample. This suggests that societies that are more vulnerable to larger shocks to inequality tend to be more willing to resort to government to provide social services. This would be a Rawlsian interpretation of how to hedge one’s exposure to inequality under a “veil of ignorance” about the future: insofar as social services are usually targeted at the lower end of the income distribution, they can be seen as a kind of insurance against higher market income inequality. Such correlations are shown as simple bivariate scatterplots in Figure 6.

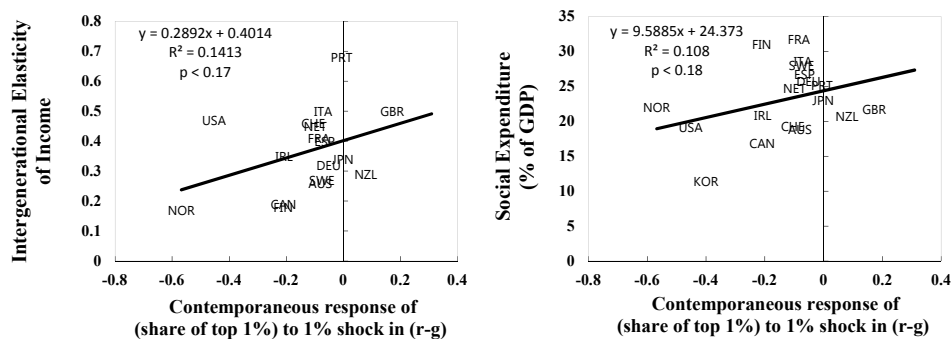


Figure 6: **Correlation between heterogeneous responses and intergenerational elasticity of income and social expenditure, respectively.** Data on intergenerational elasticity of income from Corak (Miles Corak, 2016) and Causa and Johansson (Orsett Causa and Åsa Johansson, 2013). Data on social spending from the OECD’s social expenditure database.

However, these results need to be taken with caution, since the regressions slopes are not statistically significant at standard critical levels. This could be either a byproduct of the small cross-sectional dimension of the sample or an indication that in a broader sample these results would not hold. Exploring further the causes and consequences of the heterogeneity in the relationship between $r - g$ dynamics and inequality is a potential avenue for future research.

I then turn to **Model 2**, which checks the relationship between $r - g$ and the capital share. This specification can be thought of a direct test of Piketty's model, since his extrapolations to inequality stem from a growth in the capital share.

The results are less clear-cut than with Model 1. However, in the first two years, at least 75% of the countries capital share responds (mildly) negatively to positive shocks to $r - g$, with the median approaching zero asymptotically (see Figure 7). The median response is not statistically significant but its sign of the point estimate is the opposite of what is predicted by theory (see Figure 8).

The median response of $r - g$ to capital share shocks is negative and statistically significant. This is intuitive since it is possibly reflecting diminishing marginal returns on capital—for any fixed growth rate, increased capital shares are likely to decrease returns and hence drive $r - g$ down over the new BGP. When compared to Model 1, idiosyncratic shocks are more dominant (see Figure 9).

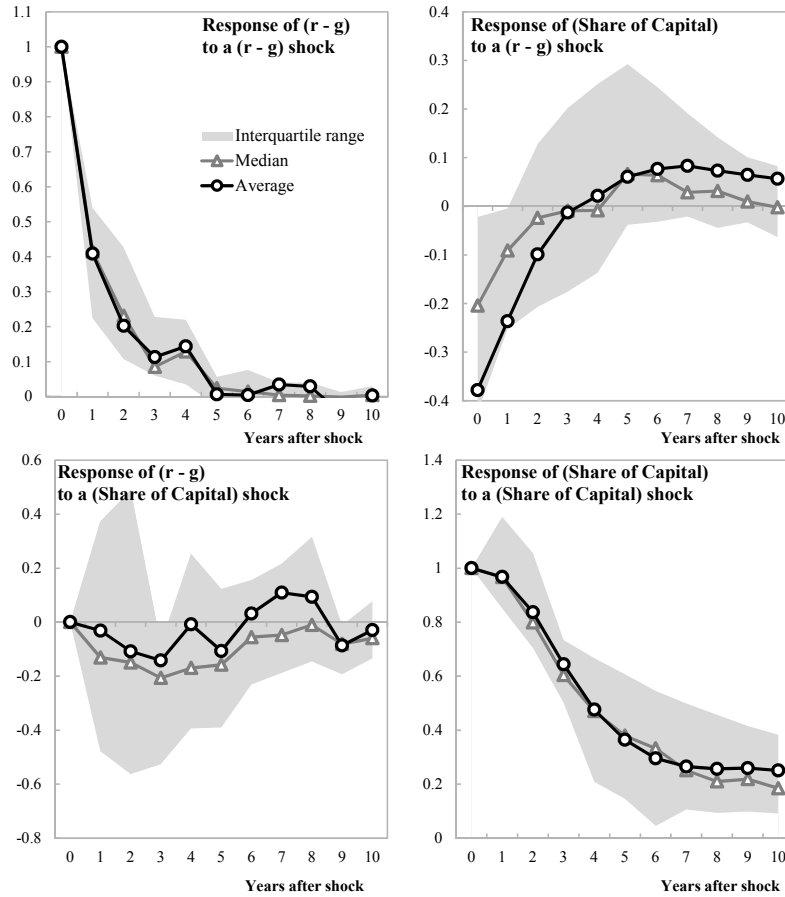


Figure 7: **Model 2: Heterogeneous composite impulse responses across sample.** The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 18 cross-sections.

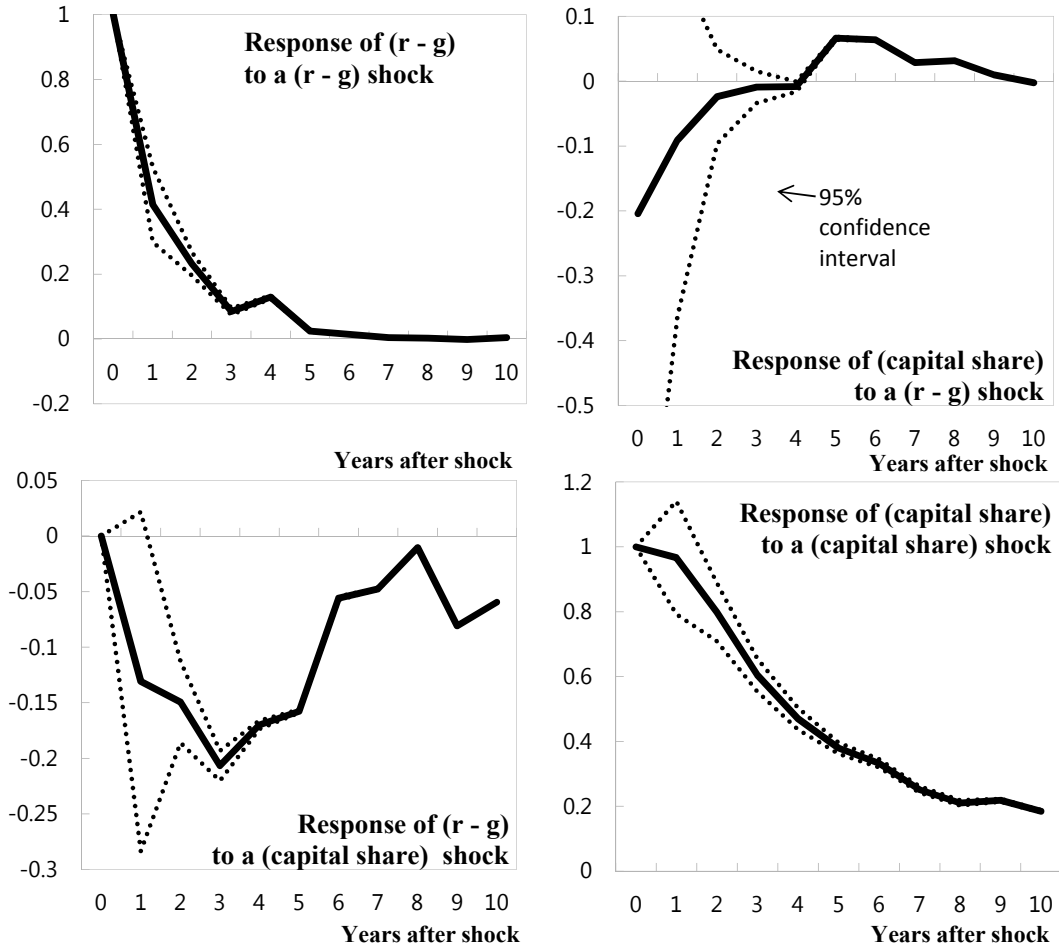


Figure 8: **Model 2: Median composite responses and confidence intervals.** Median response across a heterogeneous distribution of IRFs across 18 countries. Confidence intervals calculated from a resampling simulation with 500 repetitions. Since the distribution might change for each repetition in the simulation exercise, the confidence intervals do not represent the uncertainty around estimates for any particular country, but rather for the median estimate of the whole panel.

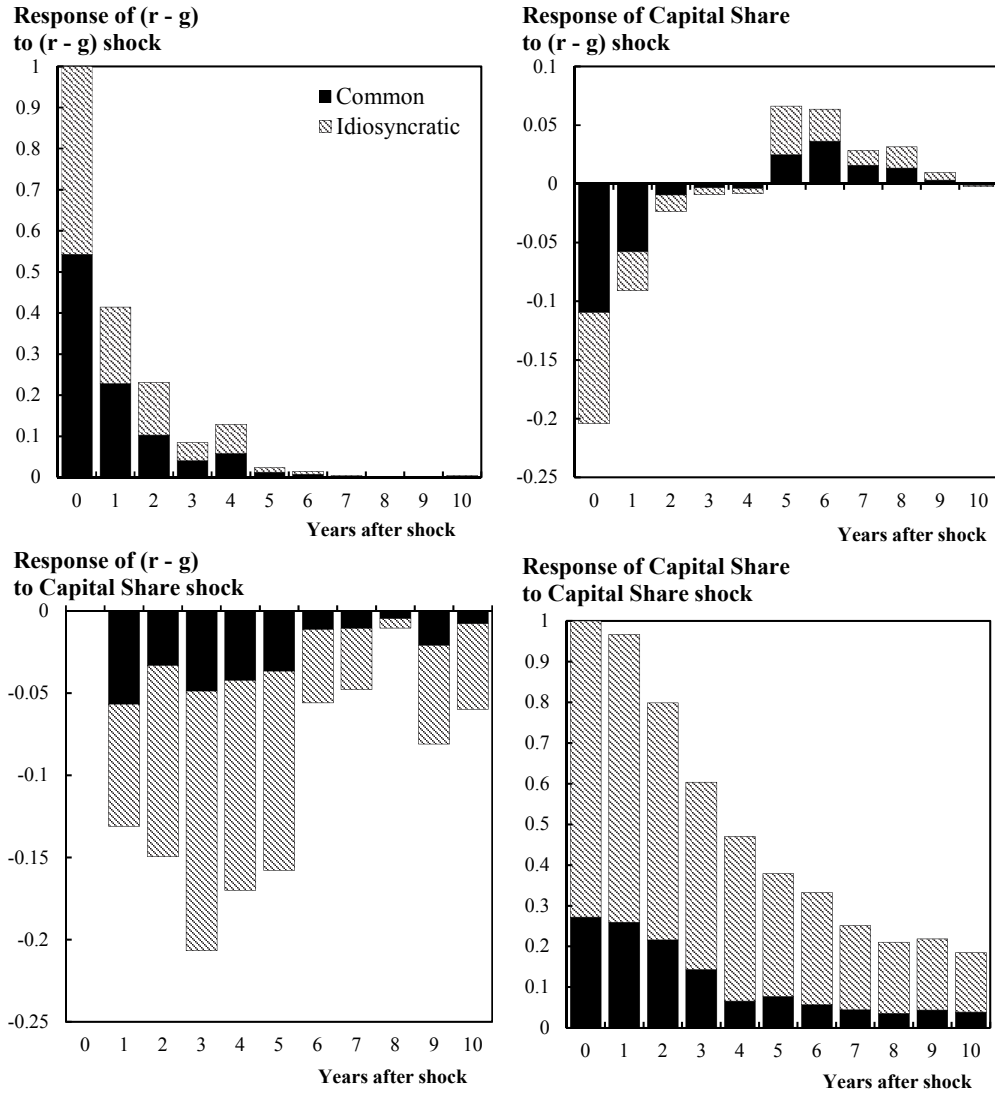


Figure 9: **Model 2: Decomposition of median composite responses.** Median responses can be decomposed into country-specific responses to common shocks and responses to idiosyncratic shocks through use of loading factors that denote the relative importance of common shocks for each country

Such result seems unusual, as even in standard models one should expect the capital share to increase following $r - g$ shocks. However, the absence of such evidence can be explained by the fact that it is unreasonable to assume that the savings rate is exogenous to $r - g$. In fact, there are strong theoretical reasons why savings rate should behave pro-cyclically. For instance, if a share of individuals move away from a borrowing constraint due to an expansion in the economy, the aggregate savings rate is expected to increase. In line with this theoretical rationale, changes in the savings rate in this sample are positively and statistically significantly correlated with GDP growth rates (see Figure 10).

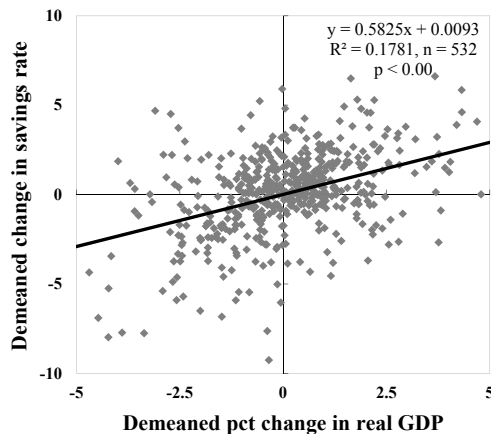


Figure 10: **Contemporaneous correlation between GDP growth and changes in the savings rate.** The sample refers to an unbalanced panel of 18 advanced economies ranging from 1981-2012. Variables are demeaned to account for time-invariant, country-specific characteristics.

Since lower growth rates are associated with a decrease in savings rates, it is hard to know *a priori* the net effect of lower growth (which, all other things equal, are equivalent to a *positive* $r - g$ shock) on the capital share. This happens because, if the decrease in the savings rate is large enough, it can offset any predicted effect of a $r - g$ shock on the capital share. To account for this, **Model 3** includes the savings rate as an endogenous variable.

The relationship observed with basic contemporaneous correlations is also reflected in the impulse response functions. For at least 75% of the countries, the savings rate responds negatively to a positive shock to $r - g$ (see Figure 11). The median response of the savings rate to $r - g$ shocks is large, negative, and statistically significant throughout the 10-year response horizon (see Figure 12). This result explains the apparent contradiction of the capital share responding negatively to such shocks.

The median response of the capital share to $r - g$ shocks is not statistically significant, as dynamics are incorporated, the median cumulative response of the capital share quickly nets out to somewhere close to zero (see Figure 12). Common shocks contribute substantially to capital share dynamics in Model 3 (see Figure 13).

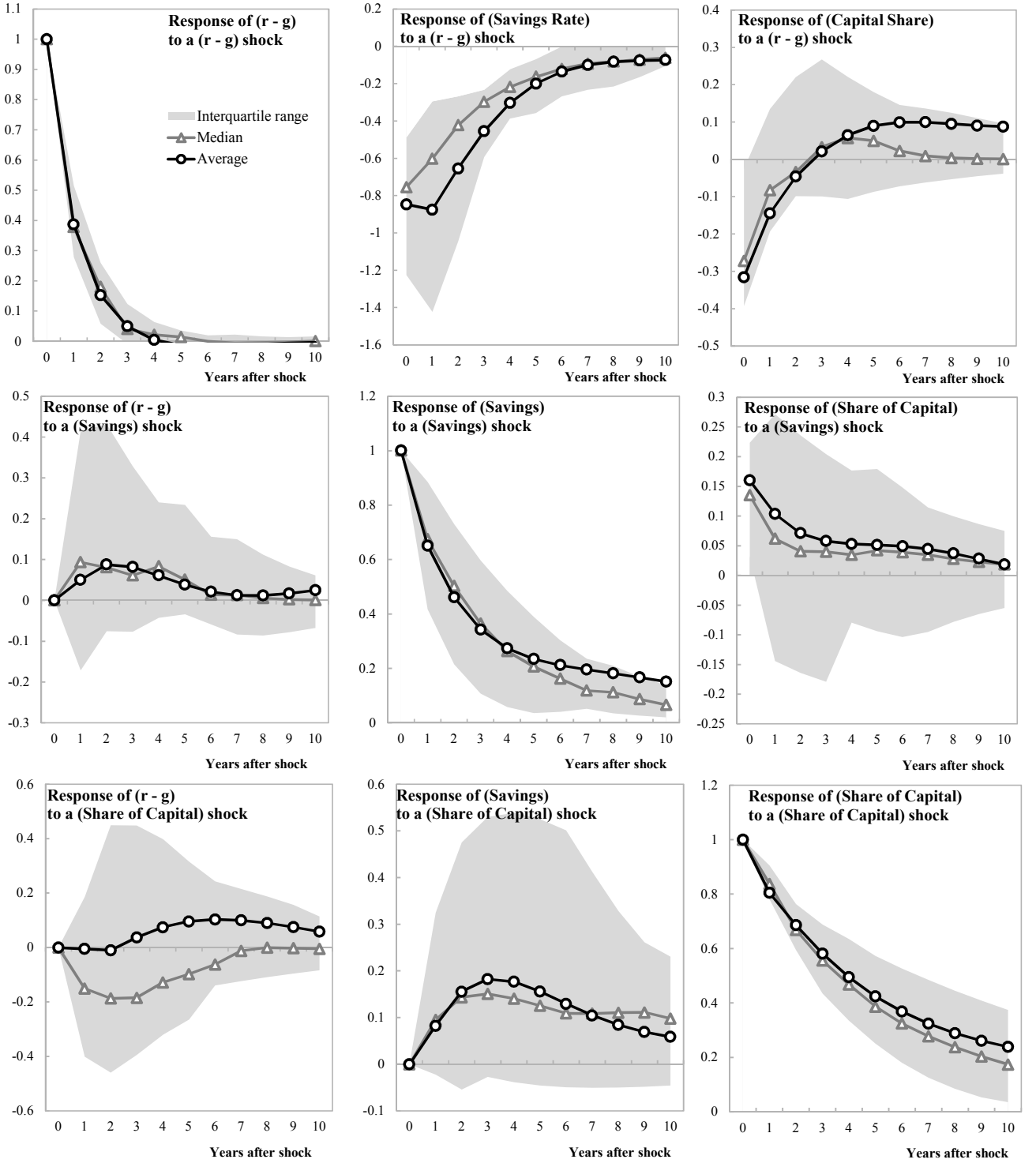


Figure 11: **Model 3: Heterogeneous composite impulse responses across sample.** The median, averages, and interquartile ranges were calculated from the distribution of IRFs of the 18 cross-sections.

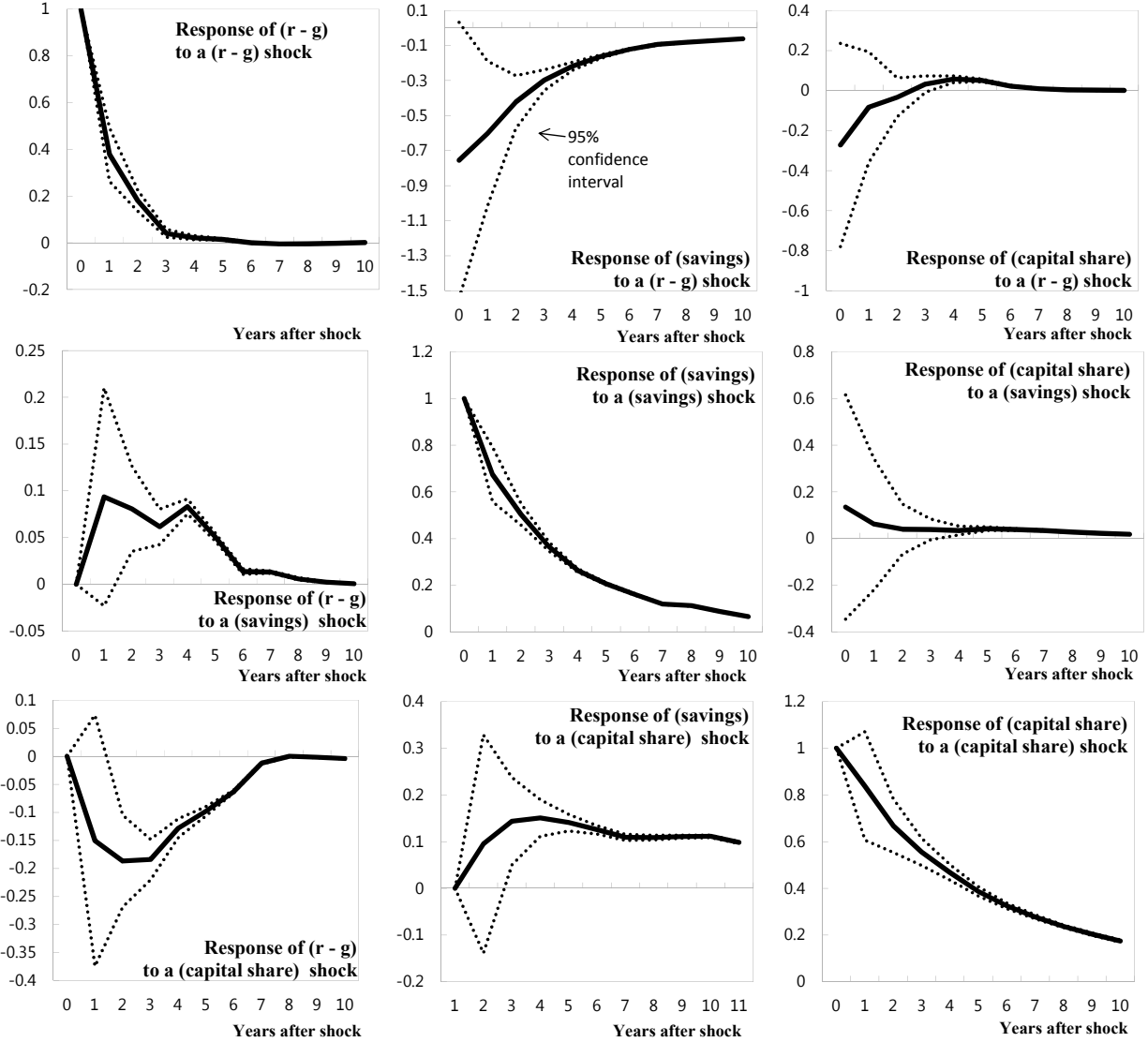


Figure 12: **Model 3: Median composite responses and confidence intervals.** Median response across a heterogeneous distribution of IRFs of 18 countries. Confidence intervals calculated from a resampling simulation with 500 repetitions. Since the distribution might change for each repetition in the simulation exercise, the confidence intervals do not represent the uncertainty around estimates for any particular country, but rather for the median estimate of the whole panel.

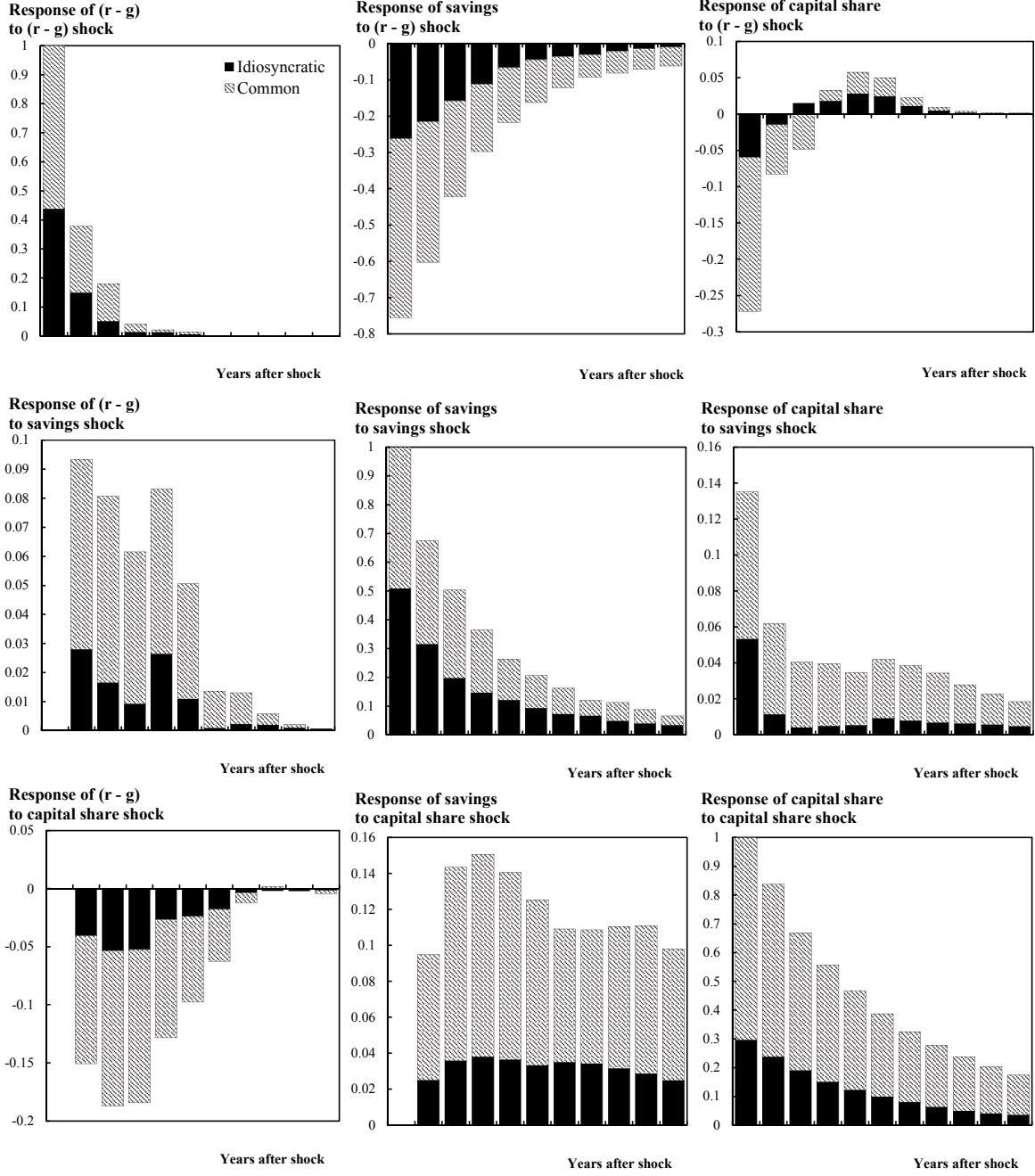


Figure 13: **Model 3: Decomposition of median composite responses.** Median responses can be decomposed into country-specific responses to common shocks and responses to idiosyncratic shocks through use of loading factors denoting the relative importance of common shocks for each country

6 Robustness

I run several alternative specifications to check the robustness of results. I do that by modifying baseline Models 1 and 3. I present all alternative results in Figure 14.

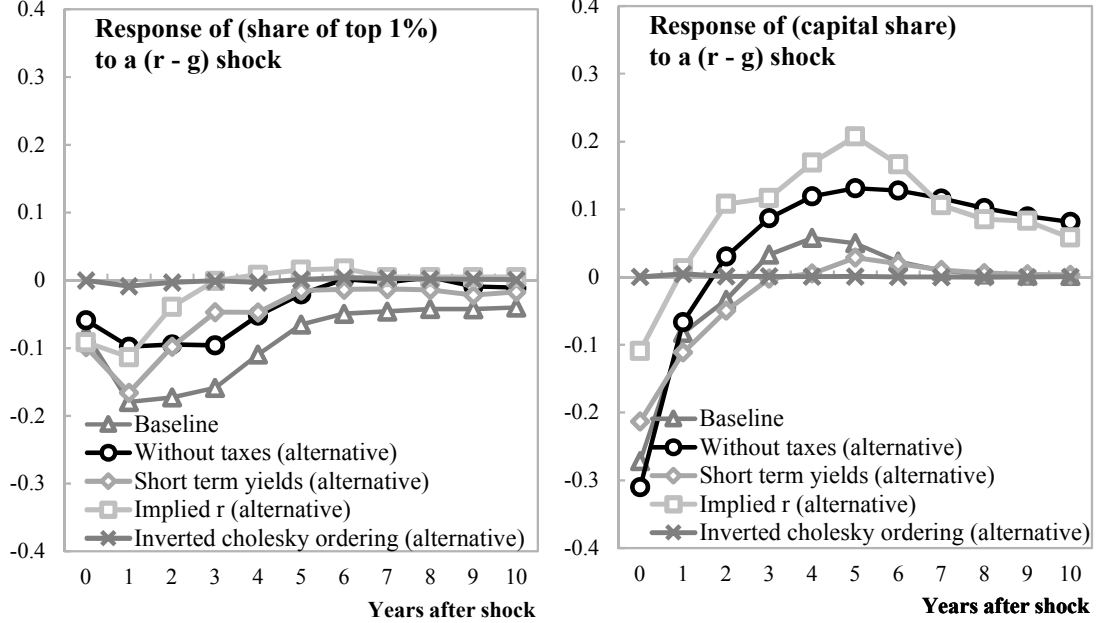


Figure 14: **Robustness checks - re-estimation of Models 1 and 3: Median composite responses.** This figure compares median responses across a distribution of IRFs of 19 (Model 1) / 18 (Model 3) countries using different specifications.

First I run an alternative model ignoring tax rates. Tax rates are important for inequality, as pointed out by Piketty and Saez (2013), but it could be that deducting tax rates from returns is adding noise to the results. However, when re-estimating the models without taking taxes into account, the results are similar to the baseline. The median responses of the share of the top 1% to $r - g$ shocks are still negative, albeit not as negative than in Model 1.

When replacing long-term bond yields with short term yields (usually central bank policy rates), median responses are very similar to the baseline for the initial response horizons. In outer years, responses net out to zero faster than in the baseline.

I then re-estimate the models using an implied measure of r from the national accounts. Deriving this measure is straightforward. Since capital share is the return on capital times the capital-to-income ratio ($\alpha = rK/Y$), it follows that the return on capital is the capital share divided by the capital-to-income ratio ($r = \alpha Y/K$). After calculating implied returns on capital for all countries from the Penn World Tables, I deducted growth rates and re-estimated Model 1. Median responses still behave comparably to all other specifications, hovering close to zero.

Overall, the results are rather robust to different measures of r . There is no evidence that the share of the top 1% responds positively to increases in $r - g$ spread.

Similarly, for the capital share, despite small differences, the results are virtually the same as in Model 3—with the savings rate playing a counter-balancing role after $r - g$ shocks and median capital share responses going from negative to slightly positive before converging towards zero.

Finally, I re-run both models with an inverted Cholesky ordering, i.e. with the share of the top 1% and the share of capital in the national income as the most exogenous variable. It could be the case that the original restrictions imposed on the baseline specifications were hiding a positive effect of $r - g$ over share of the top 1% and the share of capital. However, in the alternative specification, such effects are very close to zero, which renders them both statistically and economically insignificant. Yet again, in this last alternative specification, there is no evidence in support of Piketty’s hypotheses of $r - g$ increasing the capital share and income inequality.

While baseline conclusions are reasonably robust to all the different specifications estimated, there are several other possible extensions of the empirical models which can provide additional robustness to the results. These include, for instance, using the Penn World Table’s estimates of time-varying depreciation rates, using measures of equity prices as a proxy for the return on capital, incorporating foreign savings to the model, or using a different measure for inequality (such as, for instance, the Gini coefficient).

7 Discussion: What is the Takeaway?

Piketty’s conclusion that inequality will increase in the future rests on the underlying assumption that, as growth decreases over time, driving the $r - g$ spread to increase, capital-to-income ratios will increase. However, the results from Model 2 and Model 3 fail to show robust positive responses of capital share to shocks in $r - g$ and cast doubt on Piketty’s conjecture. A possible reason for this is that Piketty could be underestimating diminishing returns of capital—thereby overestimating the elasticity of substitution between capital and labor, whose empirical estimates tend to be much lower than what he assumes (Rognlie, 2014). This relationship is illustrated in this paper by the negative median responses of $r - g$ to positive capital share shocks.

Another less emphasized but equally important problem with Piketty’s conjecture is highlighted by Krusell and Smith (2015), who argue that Piketty’s predictions are grounded on a flawed theory of savings—namely, that the savings rate net of depreciation is constant—which exacerbates the expected increase in capital-to-income ratios as growth rates tend to zero. They present an alternative model in which agents maximize inter-temporal utility and arrive in a setting in which, on an balanced growth path, the savings rate is pro-cyclical. By showing that the savings rate responds negatively to negative growth shocks (which, in turn, are translated into positive $r - g$ shocks) for at least 75% of the countries in the sample, the results of Model 3 provide empirical support to Krusell and Smith’s analysis.

Piketty (2012) says in his online notes: “with $g = 0\%$, we’re back to Marx apocalyptic conclusions,” in which capital share goes to 100% and workers take home none of the output. While this is logically consistent with the model’s assumptions, empirically there seem to be endogenous forces preventing that: non-negligible diminishing returns on capital and pro-cyclical changes in the savings rate. These are two different ways in which the transmission mechanism from $r - g$ to the capital share might be blocked: with the former, at the limit the rate of return on capital tends to zero and there is no dynamic transmission; with the latter, if growth approaches zero, the savings might ultimately become zero, offsetting any effect of lower growth on capital share. They are, however, fundamentally different: the first regards the production function and technological change, while the second has to do life-cycle behavior of capital owners.

Regarding inequality, the results from Model 1 contradict Piketty’s prediction stating that following exogenous shocks in $r - g$ inequality should increase. In fact, for at least 75% of the countries in the sample, the result is negative. These findings are in line with previous results by Acemoglu and Robinson (2015), who found negative coefficients in single-equation panel models when regressing $r - g$ on the share of the top 1%. This paper goes further, not only because the model takes all variables as endogenous, but also because it incorporates tax variability across countries. Additionally, by decomposing between common and idiosyncratic shocks, rather than using time dummies, Model 1 does not throw away potentially important information about the effect of structural forces (e.g., globalization) on these dynamics—which, as Milanovic (2014) argues, is a problem with Acemoglu and Robinson’s analysis.

The fact that a positive $r - g$ spread does not lead to higher inequality is not necessarily surprising. As illustrated by Mankiw (2015) through a standard model that incorporates taxation and depreciation, even if $r > g$, one can arrive in a steady state inequality which does not evolve into an endless inegalitarian spiral. Milanovic (2017) explains that the transmission mechanism between $r > g$ and higher income inequality requires all of the following conditions to hold: (a) savings rates have to be sufficiently high; (b) capital income needs to be more unequally distributed than labor income; and (c) a high correlation between drawing capital income and being on the top of the income distribution. In a dynamic fashion, this paper shows that the negative responses of the savings rate to $r - g$ shocks violate the first condition, thereby preventing higher levels of inequality when compared to those observed before the increases in $r - g$.

Since estimated dynamics do not confirm Piketty’s theory, observed income inequality in many advanced economies over the past decades is probably explained by factors other than the spread between r and g . In fact, there is evidence that recent inequality trends are not related to the distribution of national income between factors of production but primarily to the rising inequality of labor income (Francese and Mulas-Granados, 2015). Indeed, there are many potential explanations for the rising labor income inequality—as, for instance:

- Dabla-Norris et al. (2015), after evaluating cross-country evidence, find that past changes in inequality in advanced economies are associated the most with two labor market changes: higher skill premia and lower union membership rates. Jaumotte and Buitron (2015) also present results that correlate changes

in labor market institutions, particularly lower union density, with increases in income inequality in advanced economies.

- Aghion et al. (2015) suggest innovation plays a significant role. If innovators are rewarded with higher incomes due to a temporary technological advantage (in a Schumpeterian fashion), inequality would be exacerbated. The authors show that innovation explains about a fifth of the higher inequality observed in the U.S. since 1975.
- Mare (2016) and Greenwood et al. (2012) argue that changes in mating behavior helped exacerbate income inequality. The probability that someone will marry another person with a similar socio-educational background (labeled “assortative mating”) increased *in tandem* with the rise in income inequality in U.S. in the recent decades. The interaction between higher skill premia and higher assortative mating exacerbates household income inequality, because the gap between higher and lower earners became larger and couples became more segregated.
- Chong and Gradstein (2007) use a dynamic panel to show inequality tends to decrease as institutional quality improves. The underlying logic is that if the basic rules of economic behavior are not symmetrically enforced, the rich will have a higher chance to extract economic rents, thereby increasing inequality. Acemoglu and Robinson (2015) make a similar argument. They say that economic institutions affect the distribution of skills in society, indirectly determining inequality patterns.
- Another potential source of explanation regarding why it might be difficult to find in the data empirical evidence for the causal links set forth by Piketty is *income concentration mismeasurement*. I relied on the preferred set of estimates by Piketty and his coauthors to test his hypothesis, those from *World Inequality Database*. However, an emergent literature shows that the measurement of top income can be highly uncertain. A large share of income flows is unobserved and its estimation depends on assumptions regarding its distribution and valuation. For instance, Auten, Splinter and Furchtgott-Roth (2021) present alternative series for top income shares, using different assumptions, and conclude that the after-tax income share for top 1% of incomes in the United States stayed flat in the last half-century.

None of the evidence provided in the papers listed above is definite or mutually exclusive. Rather, they are most likely complementary explanations for the recent developments of a complex phenomenon such as income inequality. But what they do have in common is that none of them point to capital-to-income or $r - g$ dynamics as the driving causes of inequality patterns.

Some years after the publication of *Capital*, Piketty (2015) himself recognized the “rise in labor income inequality in recent decades has evidently little to do with $r - g$, and it is clearly a very important historical development.” He nonetheless emphasized that a higher $r - g$ spread will be important and will exacerbate future inequality changes.

However, the results in this paper show that this is likely not to be the case. The results corroborate the idea that recent inequality changes are not explained by $r - g$ but also that new shocks to $r - g$ will likely not lead to higher inequality, as there is no evidence that shocks to $r - g$ increase income inequality. Combined, the observed endogenous dynamics of $r - g$ and the share of the top 1% and the capital share, respectively, cast doubt on the reasonability of Piketty’s prediction about inequality trends.

A potential caveat of this analysis is that my sample size might be too short to capture the long-run relationship under scrutiny. While this is certainly possible, there are some limits to such criticism. First, since the focus of the exercise is advanced countries, one expects them to be close to their respective BGPs. In such a case, it is more likely that the thirty-year sample is enough to capture the steady states and the effect of shocks that disturb such steady states. Second, Acemoglu and Robinson (2015) run single-equation models using 10- and 20-year averages going back to the 1800s and find no statistically significant evidence that increases in $r - g$ positively impact the share of the top 1% in the national income. Unfortunately, using those multi-decennial averages in an endogenous dynamic panel framework would render the identification restrictions so strong (namely, that one variable has no impact over the other for 20 years) that it would make the entire exercise futile.

8 Conclusions

The purpose of this paper is very Popperian in nature: it tests interesting, logically consistent, and falsifiable hypotheses. Thereby, it contributes to the literature by checking the empirical veracity of a very influential theory regarding income inequality patterns.

In doing so, I found no evidence to corroborate the idea that the $r - g$ gap drives the capital share in national income. There are endogenous forces overlooked by Piketty —particularly the cyclicity of the savings rate —which balance out predicted large increases in the capital share. On inequality, the evidence against Piketty’s predictions is even stronger: for at least 75% of the countries, the response of inequality to increases in $r - g$ has the opposite sign to that postulated by Piketty.

These results are robust to different calculations of $r - g$. Regardless of taking the real return on capital as long-term sovereign bond yields, short-term interest rates or implied returns from national accounting tables, the dynamics move in the same direction. Additionally, including or excluding taxes does not alter the qualitative takeaways from the results either.

The policy implications of high levels of inequality can be quite important. There are different mechanisms, not evaluated in this paper, that suggest that inequality can be harmful to social welfare. For instance, Alesina and Rodrik (1994) set forth an endogenous growth model in which capital taxes increase returns to labor, inducing a conflict between capital owners and workers regarding the optimal tax rate in the presence of inequality in capital ownership. Banerjee and Newman (1993) develop a model with capital market imperfections in which long-run prosperity depends on the initial wealth distribution. Easterly (2007) provides

evidence that initial land endowment predicts future inequality and future inequality predicts development. Campante and Ferreira (2007) draw up a theory and Shughart II et al. (2003) provide suggestive evidence that heterogeneity in the capabilities of interest groups can reinforce income inequality.

Without knowing the underlying causes of the recent trends in increased income inequality, it is impossible to design policy actions to counter them. The solution advanced by Piketty and some of his co-authors is increased capital income or wealth taxation (see, for instance, the policy proposals in the book by Saez and Zucman, 2019). However, if the links between his theory and inequality are found wanting, these policies might not lead to the desired outcomes.

Additionally, one should take into account the potential unintended consequences of these policies. Well identified empirical studies show that workers may bear the burden of as much as 50-75% of the total corporate tax incidence (Fuest, Peichl and Siegloch, 2018; Malgouyres, Mayer and Mazet-Sonilhac, 2023; Suárez Serrato and Zidar, 2016). As the model posited by Bethencourt and Kunze (2015) rationalizes, increased inequality might lead to a preference for higher tax rates as well as a deterioration of the tax base through tax evasion. Empirically, Guyton et al. (2021) find that tax evasion is very large among top income earners in the U.S., with underreported income accounting for as much as 50% of total income. Hence, even if one abstracts away from the question of how to model optimal policy through the lens of a “benevolent social planner” or a “revenue-maximizing Leviathan” (Brennan and Buchanan, 1980), investigating the implications of this causal link between $r - g$ and inequality would be relevant for outlining optimal choices.

Knowing if increases $r - g$ lead to inequality is very important, not only for economics as a science of human action but also for the policy repercussions of such conclusions. Inequality is a complex phenomenon and its trends are very sluggish. It is certainly possible that the long-term relationships Piketty proposes exist and are simply not captured by the 30 years of data for the 19 advanced economies included in this sample. However, for a large range of countries, the evidence provided in this paper suggests that if one is looking to potential solutions to increasing income inequality, one should not focus on $r - g$, but elsewhere.

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A Appendix: Data and Sources

A.1 Countries Sample

Samples are slightly different in Model 1 compared to Models 2 and 3 to account for dynamic (in)stability in different samples.

Sample for Model 1: Australia, Canada, Finland, France, Germany, Italy, Ireland, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and United States.

Sample for Models 2 and 3: Australia, Canada, Denmark, Finland, France, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and United States.

A.2 Data Sources

Variable	Scale	Source
Share of the top 1%	Percent of national income	World Top Income Database
Capital share	Percent of national income	Penn World Tables
Real GDP growth	Annual percent change	World Economic Outlook
GDP deflators	Index	World Economic Outlook
Gross national savings	Percent of national income	World Economic Outlook
Corporate income tax rates	Percent	OECD's Tax Database
10-YR sovereign bond yields	Percent	Bloomberg & Haver Analytics
Short-term interest rates	Percent	Haver Analytics & IMF
Implied return on capital	Percent	Derived from Penn World Tables
U.S. 95th pctile wealth	Constant U.S. dollars	Congressional Budget Office

B Appendix: Standard Error Simulation Algorithm

Before starting the simulation, I run the individual VARs in equation (6) and collect predicted values ($\hat{y}_{i,t}$) and reduced form residuals ($u_{i,t}$). I then transform reduced-form residuals into their structural equivalents ($e_{i,t} = B_i^{-1}u_{i,t}$) and run the following algorithm:

1. I follow these steps $k = 500$ times:

- (a) I re-sample the structural residuals accounting for cross-sectional dependence. First, for each i , I use the loadings Λ_i to recover idiosyncratic shocks $\{\tilde{e}_{i,t}\}_{t=0}^T$, using the equations in (8) to extract $\tilde{e}_{i,t} = u_{i,t} - \Lambda_i \bar{e}_t$, where \bar{e}_t denote the common shocks.
- (b) Let $\dot{e}_{i,t}$ denote re-sampled structural residuals $e_{i,t}$. I resample common shocks $\dot{\bar{e}}_t$ and idiosyncratic shocks $\dot{\tilde{e}}_{i,t}$ and use these variables to construct resample structural residuals that incorporate the cross-sectional dependence structure of the panel as:

$$\dot{e}_{i,t} = \Lambda_i \dot{\bar{e}}_t + \dot{\tilde{e}}_{i,t} \quad (\text{B.1})$$

- (c) I then transform re-sampled structural residuals back into reduced-form residuals by multiplying them with B : $\dot{u}_{i,t} = B_i \dot{e}_{i,t}$.
 - (d) I sum the predicted values of $y_{i,t}^*$ and re-sampled residuals to create pseudo-series for all members M . Let the pseudo-series be $\tilde{y}_{i,t} \equiv \hat{y}_{i,t} + \dot{u}_{i,t}$.
 - (e) I re-estimate the model with the pseudo-series: $\tilde{B}_i \tilde{y}_{i,t} = \tilde{R}(L) \tilde{y}_{i,t-1} + \tilde{u}_{i,t}$.
 - (f) I collect the matrices of responses, extract individual vectors for each pseudo-IRF, organize them into a matrix, and calculate the median response of this distribution.
 - (g) If this repetition $< k$, I go back to (a), otherwise, I move to step 2.
2. After I repeat this procedure k times the result will be a set of distribution matrices D of simulated medians:

$$D_m = \begin{bmatrix} \tilde{\rho}_{1m}^1 & \cdots & \tilde{\rho}_{1m}^k \\ \vdots & \ddots & \vdots \\ \tilde{\rho}_{hm}^1 & \cdots & \tilde{\rho}_{hm}^k \end{bmatrix}_{h \times k} \quad (\text{B.2})$$

where m is the m^{th} response variable, h is the response horizon, and k is the number of repetitions of the simulation exercise.

3. From D_m I take square root of the second moment of each row to build a vector of standard errors:

$$\sigma_{\rho_m} = \begin{bmatrix} \text{Var}[\{\tilde{\rho}_{1m}^1, \dots, \tilde{\rho}_{1m}^k\}]^{1/2} \\ \vdots \\ \text{Var}[\{\tilde{\rho}_{hm}^1, \dots, \tilde{\rho}_{hm}^k\}]^{1/2} \end{bmatrix}_{hx1} \quad (\text{B.3})$$