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Inequality and Growth in Portugal: a time series analysis

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Abstract

Following the recent resurgence of interest on the relationship between inequality and growth and the considerable debate that remains on its sign, we examine this nexus for Portugal during the period 1985–2007 using a time series approach. The results, using different time series methodologies, suggest that earnings inequality has a negative impact on output thus confirming the view that inequality is detrimental to growth. Moreover, according to the results from the impulse response functions based on the preferred trivariate structural VAR model, these effects last in some cases for three years after the inequality shock. As far as education is concerned, the third variable apart from output and inequality considered in our SVAR models, the evidence does not support the theoretical prediction that more inequality reduces human capital accumulation, pointing in fact in the opposite direction: an increase in earnings inequality leads to more educated workers. Thus, the evidence of a negative influence of inequality on output seems to be explained not by the fact that more inequality leads to less human capital accumulation but because it implies more redistribution, with the associated distortionary effects from taxes on investment.

Keywords: output, inequality, education, Hendry-Krolzig methodology, causality, SVAR

JEL classification: O12

1. Introduction

The relationship between inequality and economic growth has been comprehensively analyzed in the theoretical and empirical literature and still generates considerable amount of debate among economists. This debate revolves around two competing views or theories on the impact of inequality on growth. Earlier theories predicted a positive influence due to a higher propensity to save of the richer, with higher inequality leading to more physical and human capital accumulation and thus growth, and because it provides an incentive to the appearance of entrepeneurs/inventors expecting to belong to the wealthier part of the society, thus enhancing growth when innovation is the driving force of long run performance, as well as promoting higher effort by workers and thus efficiency (see e.g. (Perotti 1996); (Aghion et al. 1999); and (Barro 2000)). More recent theories associated with new growth theory claim that inequality is detrimental to growth. For developed countries, the negative effect of inequality on growth is justified on the basis of two main arguments or mechanisms of transmission. The credit market imperfections channel argues that these lead to lower levels of human capital investments and thus slower growth, since only initially rich individuals have the collateral to gain access to the credit necessary to invest in human capital (see e.g. (Galor and Zeira 1993)). According to the fiscal approach channel, in more unequal economies the level of redistribution demanded from the government by the population will be higher, which in turn leads to higher levels of taxation that affect investment decisions, resulting in less investment and growth (see e.g. (Alesina and Perotti 1994), and (Persson and GuidoTabellini 1994)).

Empirical analyses of the impact of inequality on economic growth include, among others (Perotti 1996), (Chen 2003), and (Balisacan and Fuwa 2003). The general picture from cross-country studies like the former is that initial inequality reduces future growth. The message from panel data studies is however not clear. For instance, among the panel studies that consider wider samples of countries with both developing and developed countries, (Deininger and Squire 1998) find that the sign of the relationship is ambiguous and even positive in some cases; (Forbes 2000) detects a positive relationship that persists across different samples, variables definitions, and model specifications but not the length of period under consideration; (Barro 2000) uncovers a negative relationship for poor countries, a positive relationship for rich countries, and an insignificant one for the whole sample; (Banerjee and Duflo 2003) present evidence that it is a change in any direction, not the initial level of inequality that leads to slower future growth; and (Voitchovsky 2005) using data on inequality for industrialized countries concludes that top end inequality positively influences growth while the influence of bottom end inequality is negative. In face of the mixed evidence provided by empirical studies, (Dominicis et al. 2006) apply meta-analysis to a set of twenty-two studies, that give a total of 254 estimates for the coefficient of the inequality measure[1], with the results showing that the variation in the estimates of the income inequality-growth relation are systematically associated with differences in estimation methods, sample coverage and data quality.

Time series studies are scarcer. For instance, (Gobbin and Rayp 2008) apply Johansen's cointegration methodology to the analysis of the relation between income inequality and economic growth in Belgium, the US and Finland[2], finding quite different results in each case, which leads them to conclude that: "A country- specific estimation approach is needed since 'one-size-fits-all' does not apply in the field of growth empirics. " (p. 892). (Frank 2009) uses a time series approach to examine the relationship between income inequality, human capital attainment, and income growth in a sample of US states over the period 1929–2000. He finds evidence that a rise in the top income share has a negative impact on output growth and that this relationship is stronger in more densely populated states. (Risso and Carrera 2010) study the long-run relationship between economic growth and income inequality in China using a cointegrated VAR approach. The results point to a positive and significant relationship between inequality and growth in the two periods under analysis, 1952-1978 and 1979-2007.

There is also considerable debate around whether the causality runs from inequality to growth or primarily the other way around. Since the seminal work of (Kuznets 1955), that found an inverted U-shaped relation between per capita output and (income) inequality, several studies provide evidence of a reverse causal relationship from growth to inequality. For instance, (Assane and Grammy 2003) use a trivariate VAR model comprised of per capita real GDP, the Gini coefficient of income, and human capital to

[1] The authors point out "(...) the large heterogeneity in the sample, with around 40% of the values showing a negative value, and an equal amount of estimates that exhibits a value close to zero. Only the remaining 20% of the estimates are positive." (Dominicis et al. 2006), p. 10.

[2] In most cases for the period 1960-2000.

assess the causal relationship between income inequality and growth in the US over the period 1960-1996 and find that it is growth that causes inequality, with inequality increasing as growth proceeds. However, (Frank 2009) finds only weak evidence that income growth Granger-causes the top decile income share, and (Risso and Carrera 2010) find a unidirectional causality from inequality to growth in China and only during the first period analyzed, 1952-1978.

Following this recent resurgence of interest in the relationship between inequality and growth, this paper examines this relationship for Portugal during the period 1985–2007 using a time series approach to characterize the dynamics of output in response to inequality shocks. In the period immediately after joining the European Union (EU) in 1986, Portugal grew at an encouraging growth rate of around 4% per annum, in per capita terms, but in a more recent period, 2000-2007, it has almost stagnated with an average annual growth of real GDP per capita around 0.6%. This dismal aggregate performance was accompanied by an increase in income inequality as measured by the Gini coefficient. This paper contributes to the literature by focusing on the experience of a single country, thus avoiding data comparability issues (see e.g. (Knowles 2005)), and by exploring time series data that allows to overcome some of the problems of cross section (omitted variable bias) and panel data empirical growth studies (parameter heterogeneity and endogeneity), as pointed out by (Gobbin and Rayp 2008). Additionally, it fills a gap in the empirical analysis of economic growth in Portugal by focusing on a growth determinant that is missing in previous studies (see e.g. (Teixeira and Fortuna 2004; Teixeira and Fortuna 2010) and (Pereira and St Aubyn 2009)) and might be extremely relevant for this specific country. The paper is also original in its application of a SVAR model to study the relationship between inequality, human capital and growth in a developed country, in this case Portugal, using inequality indicators computed by the authors and not from secondary sources. Moreover, inequality indicators based on earnings allow us to measure inequality in Portugal without considering the impact of redistribution policies. Thus these indicators are the most suited to portrait inequality before redistribution, e.g., to the empirical analysis of the fiscal mechanism explaining the relationship between inequality and economic growth.

The paper proceeds as follows. In the next section, we present the econometric methodology and results. Section 3 offers some concluding remarks.

2. Econometric methodology and results[3]

We apply time-series analysis to examine the relationship between inequality and growth in Portugal. For this purpose we use annual data for the period 1985–2007 for three variables: output, *y*; inequality, *I*; and human capital/levels of education, *E*.

Output, *y*, is measured as the log of GDP per capita at 2000 prices taken from the European Commission's AMECO database. The earnings and years of education data are computed from the *Quadros de Pessoal* (QP) database[4], a rich Portuguese dataset with detailed and comprehensive information on workers and firms, which is the result of an annual compulsory survey conducted by the *Ministério do Trabalho e da Solidariedade Social (MTSS)* where firms are required to provide information about their workers on items such as monthly compensation, highest schooling level attained, age, and monthly hours worked.

We measure earnings as average full earnings of the employees that performed complete working hours during the month of October of the corresponding year. We excluded workers that earned less than the minimum wage, which corresponds to considering a minimum of 1,424,415 workers in 1985 and a maximum of 2,234,500 in 2007, across 308 geographic units and 17 economic activities. Due to data availability from QP we concentrate our analysis in the period that begins in 1985 and ends in 2007. Earnings values were deflated by the harmonized consumer price index (HCPI)[5] for Portugal.

Inequality, *I*, is proxied by three different measures of inequality in the distribution of earnings: *G* the Gini coefficient; *Q*_10_90, the ratio of percentile 10% over percentile 90% of employees earnings; and *Q*_25_90, the ratio of quartile 25% over percentile 90% of employees earnings. A rise in the Gini coefficient is thus equivalent to more inequality, while a rise in each of the percentiles ratios means less inequality. The Gini coefficient captures the impact of changes in the overall earnings distribution; the *Q*_10_90 ratio concentrates on the impact of changes in the left tail of the distribution capturing better the influence of inequality upon growth through the credit markets imperfections channel; and the *Q*_25_90 ratio focuses on the middle of the distribution (it can be considered as a proxy for the size of the middle class) capturing

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[3] In all estimations we follow (Pfaff 2008).
[4] Data provided by GEP-MTSS.
[5] Base year 2000.

better the growth impact of inequality through the demand for more redistribution predicted by the fiscal policy channel.

To get a proxy for the level of education of the workforce, *E*, we multiplied the ratio corresponding to the number of employees with at least 12 years of schooling over the total number of employees from the QP database by total civil employment taken from AMECO database. In this way we control for the effects of the steady increase in the number of firms included in QP database over the years.

Unit root tests

As a preliminary step to investigate the link between inequality and growth in Portugal, we test for the order of integration of variables. We examine the unit root properties of the variables in Table 1 that presents the results of the augmented-Dickey-Fuller (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests, since the ADF-tests are known to have low power for highly persistent series. As far a *y* is concerned, the ADF and KPSS tests do not allow for an unambiguous classification. Nevertheless, the KPSS test for the first difference of *y* around a constant and around a constant and a trend does not reject the null of stationarity indicating in this way that *y* is integrated of order one (*I(1)*). As for the inequality measures, *G*, *Q*_10_90 and *Q*_25_90, both tests indicate that they are integrated of order one, *I(1)*. Finally, the proxy for human capital, *E*, can be considered as stationary, in levels, around a trend[6].

Table 1: Results for the ADF and KPSS Unit Roots Tests

Variable	D	l	t_α	$F_{\alpha,D}$	$KPSS_\tau$	$KPSS_\mu$
y	c,t	1	-2.90	7.27**	0.19*	
y	c	1	-3.21**	6.40**		0.81
dy	c,t	0	-2.91	4.25	0.06***	
dy	c	1	-1.86	2.06		0.47*
G	c,t	0	-3.30*	5.54	0.13**	
G	c	0	-2.04	2.17		0.57*
dG	c,t	0	-5.44***	14.90***	0.05***	
dG	c	0	-5.59***	15.63***		0.08**
*Q*_10_90	c,t	1	-2.56	3.43	0.13**	
*Q*_10_90	c	1	-1.31	1.07		0.54*
*dQ*_10_90	c,t	0	-5.98***	17.97***	0.05***	
*dQ*_10_90	c	0	-3.68**	6.79**		0.12***
*Q*_25_90	c,t	0	-3.18	5.28	0.13**	
*Q*_25_90	c	0	-1.92	1.92		0.52*
d*Q*_25_90	c,t	0	-6.01***	18.13***	0.05***	
d*Q*_25_90	c	0	-6.15***	18.92***		0.11***
E	c,t	2	-5.03***	13.22***	.06***	

[6] Since the unit root tests show that some series display trending patterns, we allowed for these trend in the econometric analysis. However, the trend was not statistically significant so we dropped it from the analysis.

E	c	2	0.22	3.93		0.87
dE	c,t	1	-6.68***	23.37***	0.06***	
dE	c	1	-6.92***	24.37***		0.08***

Notes: *d* is the first difference of the variable. Column "D" contains the deterministic components - constant and trend (c,t) and constant only (c). "l" is the number of lags in the ADF equation necessary to eliminate AR errors . t_α is the usual t-test for the null of a unit root and $F_{\alpha,D}$ is an F test for the null of α and the deterministic part. The appropriate critical values are reproduced in (Hamilton 1994). "*", "**" and "***" mean rejection at the 10%, 5%, and 1% significance levels, respectively, of the null hypothesis. For the KPSS test we use the short lag determination $(4\dot{n}/100)^{1/4}$, which is equal to 2. "*", "**", and "***" mean it is not possible to reject the null of stationary at the 1%, 5% and 10% significance levels, respectively. $KPSS_\tau$ is the KPSS test with a constant and around a trend and $KPSS_\mu$ is the KPSS test with a constant.

Equation dynamization and the long-run equilibrium of y

We begin our empirical study of the relationship between inequality and growth by the dynamization of *y*, considering that *y* depends only on one of the inequality measures considered in this paper and education, and restricting this dependency to a maximum of three lags given the limited number of observations. We also deduct the corresponding long-run equation.

Table 2 contains the results of applying the Hendry-Krolzig methodology of general-to-specific modelling[7] to the behaviour of *y*. In all three equations, Eq_1, Eq_2, and Eq_3, the relation between output and inequality is negative, conditioned on the positive influence of the level of human capital on output[8].

Table 2: Dynamic estimations for *y*

	Eq_1	Eq_2	Eq_3
Constant	0.378***		
y_{t-1}	0.660***	0.846***	0.833***
G_{t-2}	-0.841***		
G_{t-3}	-0.657***		
E_{t-1}		0.034**	
E_{t-2}	0.042**		0.034**
E_{t-3}	0.075***		
$Q\_10\_90_{t-1}$		0.401***	
$Q\_25\_90_{t-2}$			0.407***
σ	0.010	0.015	0.014
BIC	-8.594	-8.160	-8.230
AR(1)	1.399	0.878	0.771
ARCH(1)	0.437	0.646	2.031

[7] See e.g. (Campos et al. 2003), (Hendry and Krolzig 2003), and (Hendry and Krolzig 2005).
[8] The usual CUSUM test allows us to reject the possibility of structural change during the period under analysis in all the equations. See e.g. (Ploberger and Krämer 1992). Results are available from the authors upon request.

RESET	1.319	0.299	0.374

Notes: BIC is the Schwarz information criteria; AR(1) is the $\chi^2(1)$, ARCH(1) represent the value of F(1,18), respectively for the LM test of auto-correlation and ARCH; RESET, from power 2 to 3, the test value of F(2,12), F(2,15) and again F(2,15), respectively. "*", "**" and "***" mean rejection at the 10%, 5%, and 1% significance levels, respectively, of the null hypothesis of each coefficient being equal to zero.

Table 3 contains the long-run equations corresponding to the dynamic equations in Table 2, confirming the short-run results of a negative influence of inequality on output, whatever the inequality measure used, and a positive impact for education.

Table 3: Long-Run estimations for y

	Eq_1	Eq_2	Eq_3
Constant	1.110***		
G	-4.402***		
E	0.343***	0.221***	0.128***
***Q*_10_90**		2.595***	
***Q*_25_90**			2.445***
Long Run *σ*	0.030	0.095	0.085
Wald	188.03***	4989.5	6346.9

Notes: Wald is the value of the χ^2 statistic for the Wald test of the null of the coefficients. "*", "**" and "***" mean rejection at the 10%, 5%, and 1% significance levels, respectively, of the null hypothesis of each coefficient being equal to zero.

VAR and SVAR modelling of the inequality-growth relationship

The previous analysis considers a model with just one equation to describe the relationship between, inequality, education and growth. This kind of specification suffers from a serious drawback: it does not take into account the interdependency among variables. VAR models allow us to address this problem. Classical VAR models are useful when we want to take into account inter-dependencies and dynamic relationships between variables but they lack an underlying economic structure so VAR models evolved in the sense of incorporating a priori information on the behavior of the variables under analysis. While VAR models explain the behavior of endogenous variables by their own past values, SVAR models allow for the presence of contemporaneous interdependencies between endogenous variables (see (Breitung et al. 2004)).

A VAR model of order p, which can be interpreted as a reduced form model, can be represented by:

$$X_t = A_1 \cdot X_{t-1} + ... + A_p \cdot X_{t-p} + \mu_t \quad (1)$$

where X_t is a vector of k variables; A_i, $i = 1,..., p$ is the coefficient matrix ; μ_t a vector of order k with expected value $E(\mu_t) = 0$ and the covariance matrix $E(\mu_t \cdot \mu_t^T) = \sum_\mu$ is time invariant positive definite.

The process defined in (1) is stable if the polynomial defined by the determinant in equation (2) has no roots in or on the complex unit circle:

$$| I_k - A_1 \cdot z - \ ... - A_p \cdot z^p | \neq 0 \text{, for } | z | \leq 1 \quad (2)$$

A structural form of a VAR (SVAR) is defined as,

$$AX_t = A_1^* X_{t-1} + ... + A_p^* X_{t-p} + B\epsilon_t \quad (3)$$

where A_t^* are the structural coefficients and ϵ_t the structural errors, assumed white noise.

Pre-multiplying (3) by A^* we obtain equation (1) above, with $A_i = A^{-1} \cdot A_i^*$, and

$$\mu_t = A^{-1} B\epsilon_t \quad (4)$$

Equation (4) is in turn equivalent to:

$$A \cdot \mu_t = B \cdot \epsilon_t \quad (5)$$

where the elements of A and B are defined as $a_{i,j}$ and $b_{i,j}$, respectively.

We consider a SVAR model where the structural shocks are assumed to be independent, so $B = I_k$ (see (Pagan 1995)). The number of restrictions for exact identification is $\frac{k \cdot (k-1)}{2}$.

The parameters are estimated by minimization of the negative of the concentrated log-likelihood function, equation (6):

$$ln\ Lc(A,B) = \frac{-kT}{2} ln(2\pi) + \frac{T}{2} ln | A |^2 - \frac{T}{2} ln | B |^2 - \frac{T}{2} tr(A^T (B^{-1})^T B^{-1} A \Sigma_\mu) \quad (6)$$

where Σ_μ is an estimate of the reduced form covariance matrix of the error process.

We consider the following structural prior information for the analysis of output (*y*), inequality (*I*) and levels of education (*E*), in order to identify the structural residuals:

$$\mu^y = a_{1,2} \cdot \mu^I + a_{1,3} \cdot \mu^E + b_{1,1} \cdot \epsilon^y \quad (7)$$

$$\mu^I = b_{2,2} \cdot \epsilon^I \quad (8)$$

$$\mu^E = a_{3,2} \cdot \mu^I + b_{3,3} \cdot \epsilon^E \quad (9)$$

where ϵ^y, ϵ^I and ϵ^E will be defined as supply, distribution and human capital shocks , respectively, in order to distinguish them from the shocks in the reduced-form VAR models. The structural residuals are thus obtained by imposing the following restrictions: output is dependent on a supply (structural) shock, on inequality and on education (see e.g. (Galor and Zeira 1993), (Alesina and Perotti 1994; Alesina and Perotti 1996), and (Galor 2000)); inequality is assumed to depend only on a distribution (structural) shock, an assumption based on the specificities of the Portuguese economy during the period under analysis when changes in inequality were due mainly to institutional shocks[9]; and education is dependent on a human capital (structural) shock and on inequality, based on the predictions from growth models that analyze the impact of inequality on output through its effects on human capital briefly reviewed in the introduction[10]. The system composed of equations (7), (8) and (9) is exactly identified[11].

The different estimated VAR models are identified as M1, M2 and M3, respectively, when considering the variables y, G and E (M1); y, Q_10_90 and E (M2); and y, Q_25_90 and E (M3). Due to our relatively short data sample (1985-2007) and the well known problem of over-parameterization in VAR models we also estimate Near-VAR models where the variables retained are selected based on the estimated parameters t-values[12]. The corresponding restricted Near-VAR models are thus represented by M1R, M2R and M3R, respectively. All models include a constant term.

We start by testing for the optimal lag order of the VAR using the Schwarz Bayesian criterion (SBC):

$$SC(p) = ln\,|\tilde{\Sigma}_{\mu}(p)| + \frac{ln(T)}{T} \cdot p \cdot k^2 \qquad (10)$$

where $\tilde{\Sigma}_{\mu}(p) = \frac{1}{T}\sum_{t=1}^{T} \hat{u}_t \cdot \hat{u}_t^{'}$.

The results concerning the selection of the optimal lag order of the different models are presented in Table 4, corresponding to an optimum lag order of the VAR and Near-VAR models of four. As can be seen, the values of the SBC criterion are not very

[9] For instance, still associated with the political revolution of April 1974 when the minimum wage was first set in May 1974.
[10] Important institutional changes affected Portugal over the period 1985-2007. For instance, in 1986 it became mandatory for children to have the first 9 years of the formal education system. These are reflected in the structural shock or human capital shock.
[11] We tested other restrictions but these were the ones that produced the best results. Results are available from the authors upon request.
[12] We retain the variables for which the estimated coefficients present a t-value greater than or equal to 2.0.

different for the three VAR models, and the same applies to the corresponding three Near-VAR models. Nevertheless, we consider as the best VAR and Near-VAR models, respectively, M2, that considers *Q_10_90* as the inequality measure, and M3R that uses *Q*_25_90. In any case, according to the results of the SBC criterion, M3R is slightly better than M2. Figure A1 in the Appendix contains the representation of the actual and fitted values of the variables and the behaviour of the errors for model M3R. As we can see, M3R model's estimates of output, inequality and education are very similar to the respective actual values; inequality presents the highest errors, but nevertheless they are small; and errors autocorrelation is not a problem. This result makes it more likely that the inequality-growth relationship in Portugal is mainly explained by the fiscal approach in which the median voter plays an essential role (here proxied by the *Q*_25_90 ratio) leading us to expect a (possible) negative impact of inequality on output. Nevertheless, the SBC values for model M2 are the best across the three VAR models and the values for the Near-VAR models M2R and M3R are very similar. It thus might be argued that the credit markets imperfection channel is also a relevant mechanism in the explanation of the inequality-growth relationship in Portugal.

Table 4: SBC Criterion (4 lags) results for the VAR and Near-VAR models

M1	M2	M3	M1R	M2R	M3R
-21.5	-22.0	-21.69	-22.7	-23.02	**-23.29**

The next step in the analysis is to guarantee that we select a correctly specified VAR (or Near-VAR) model in the three variables *y*, *I* and *E*, that is a VAR with the right properties in terms of stability[13], adequate behavior of residuals in terms of normality, ARCH and serial correlation, and also one for which we can reject the hypothesis of a structural change in the parameters values.

Table 5 presents the results of the different specification tests based on the errors of each estimated equation. The roots of the companion matrix of the different VAR and Near-VAR models are in the unit-circle[14] except for model M1R. We detect no serious problems for the VAR and Near-VAR models in terms of auto-correlation, ARCH process, functional misspecification and normality. In any case, for model M1R we

[13] The VAR (Near-VAR) is stable if the absolute values of all eigenvalues of the system matrix lie on or inside the unit circle (see equation (2)).
[14] For economy of space reasons these results are not presented in the paper but can be obtained from the authors upon request.

reject the null hypothesis of correct specification at the 10% significance level in the inequality equation. For model M2, we cannot reject the null hypothesis of auto-correlation of the residuals in the inequality equation at the 10% significance level and also the null hypothesis of the presence of ARCH in the output equation at the 5% significance level. As for model M2R, we cannot reject the null hypothesis of the presence of ARCH in the education equation at the 5% significance level. For model M3, we cannot also reject the null hypothesis of auto-correlation of the residuals in the inequality equation at the 5% significance level. Finally, for model M3R we cannot reject the null hypothesis of auto-correlation of the residuals in the education equation at the 10% significance level and also the null hypothesis of the presence of ARCH at the 5% significance level in this same equation.

Table 5: Specification tests results

	M1	M1R	M2	M2R	M3	M3R
AR1						
y	2.24	0.97	1.40	1.08	1.32	0.25
I	2.96	0.99	**4.50***	1.75	**10.12****	1.44
E	0.00	0.03	3.93	3.73	2.03	**4.17***
ARCH						
y	1.23	0.29	**5.68****	0.16	0.65	0.85
I	1.21	1.93	0.37	0.31	0.98	0.01
E	2.25	0.97	2.26	**4.77****	0.96	**5.39****
RESET						
y	2.83	1.23	2.22	1.30	1.55	1.06
I	0.88	**3.06***	1.33	0.27	0.91	1.27
E	2.15	1.21	0.31	0.34	0.57	0.21
Normality						
y	1.47	4.17	2.37	1.83	1.62	1.16
I	0.80	1.42	0.02	1.89	0.77	2.09
E	3.38	1.43	0.02	0.12	0.25	1.45

Notes: AR1, ARCH and RESET from powers 2 to 3 are F statistics and Normality (Jarque-Bera) is a χ^2 statistic.

To test for the stability of the regression coefficients we follow the suggestion of (Ploberger and Krämer 1992) that have proposed to study the possibility of a structural change with a test on cumulative sums of the OLS residuals[15]. The OLS-CUSUM test results allow us to reject the null hypothesis of presence of a structural change on the

[15] See (Zeileis et al. 2002), (Zeileis et al. 2003) and (Zeileis 2006) for the implementation of the test.

values of the coefficients[16]. Figure A2 in the Appendix presents the values of the OLS-CUSUM test for the M3R model[17]. As we can see we can't reject the null hypothesis of no-structural change in any of the equations. The same applies to all the other models[18].

We next tested for the presence of Granger and instantaneous causality between the variables since, when testing for Granger causality, in the case of non-stationarity the usual asymptotic distribution of the test statistic may not be valid under the null hypothesis. The test for Granger causality is a *F*-type test for block exogeneity. The test for instant causality is a Wald-type test for nonzero correlation between the error processes of the cause variable and effect variables in the model. The null hypothesis in both tests is non-causality. Table 6 presents the results of both tests. As far Granger causality is concerned, with the exception of model M1, for which output does not Granger-cause inequality and education, every variable in the different models has a role causing the other variables involved in that same model. As for instantaneous causality, in model M1 education on does not instantaneously cause output and inequality and in model M2 output dos not cause inequality or education. In all the other models causality between the different variables applies.

Table 6: Granger and instantaneous causality tests

	Non Causality	Granger	Instantaneous
M1	$y \nRightarrow G, E$	1,45	5,27*
M1	$G \nRightarrow y, E$	3,75***	6,53**
M1	$E \nRightarrow y, G$	8,19***	4,12
M2	$y \nRightarrow Q\_10\_90, E$	4,36**	2,88
M2	$Q\_10\_90 \nRightarrow y, E$	7,05***	5,70**
M2	$E \nRightarrow y, Q\_10\_90$	6,08***	6,20**
M3	$y \nRightarrow Q\_25\_90, E$	3,69**	4,97*
M3	$Q\_25\_90 \nRightarrow y, E$	9,27***	6,80**
M3	$E \nRightarrow y, Q\_25\_90$	8,39***	6,99**

Notes: For the Granger causality test we have a F(8,18) statistic value and for the instantaneous causality test a χ^2 (2) statistics value.

[16] The same conclusion applies with different Chow tests: "1_step Chow test", " breakpoint Chow test" and "forecast Chow test". See (Hendry and Doornik 2001).
[17] The boundaries were calculated for a confidence level of 5%.
[18] Results can be obtained from the authors upon request.

In order to shed additional light on the relationship and forecasting ability of the variables in our model we also perform a variance decomposition analysis. The variance decomposition indicates how much of the forecast error variance of each variable can be explained by exogenous shocks to the variables in the same VAR or Near-VAR models with innovations to an individual variable having the possibility to affect both own changes and changes in the other variables. Analysing the decomposition of the variance (Table 7) the idea retained is that all variables have a significant role on the different models. However, education has a minor role on the explanation of *y* and *I* (see e.g. models M2, M2R, M3 and M3R). The results do not change much when considering VAR relative to Near-VAR models.

Table 7: Variance decomposition (%) for the VAR and Near-VAR Models twenty years after a shock

	M1			M2			M3		
Equations:	***y***	***I***	***E***	***y***	***I***	***E***	***y***	***I***	***E***
y	63	31	5	58	41	2	56	42	2
I	46	39	15	37	59	4	45	51	4
E	30	23	47	37	50	13	42	43	15
	M1R			**M2R**			**M3R**		
y	49	45	6	59	40	1	55	44	1
I	31	52	16	37	60	3	46	49	5
E	23	34	43	41	52	7	43	45	12

Notes: The equations are presented in the first column.

To determine and better understand the relationship between inequality and growth with our empirical model we have to estimate it in order mainly to identify the sign and the significance level of the coefficients $a_{1,2}$ and $a_{3,2}$, that give the impact of inequality on output and education, respectively, and the response of the different variables to shocks, especially distribution shocks. In order to do this we estimate structural VAR (SVAR) models based on the corresponding VAR and Near-VAR models and identify these models with the suffix "S". The structure of the errors is given by equations (7), (8) and (9). In some situations we can restrict certain structural parameters to equal zero and present a LR test of these restrictions.

Table 8 presents the results for the models with the Gini coefficient and is divided in two parts. The first part of the table presents the estimated coefficients of matrix *A* and the corresponding asymptotic t-values (see equation (5)). In the second part of the table we present the estimates of the coefficients of matrix $A^{-1}\cdot B$ (see equation (4) [19]). As we can see, a distribution shock has a negative impact on output and a positive impact on the level of education. These same conclusions apply for both VAR and Near-VAR based SVAR models. In model SM1 and model SMIR we find a positive impact of a human capital shock on output. Since the *t*-values of coefficient $a_{1,3}$ in the VAR and Near-VAR models are quite low we restrict the coefficient in both models to equal zero. This restriction is not rejected ($\chi^2(2)$=0.451 and 1.856, respectively) and so we present the corresponding estimated structural coefficients as the values of A^1 in Table 9[20]. The previous conclusion of a negative impact of a distribution shock on output is confirmed. We also detect in model M1O a positive impact of a human capital shock on output, but in model SM1RO there is no impact.

Table 8: Structural Parameters for the models with the Gini coefficient

SM1 (A)			SM1R (A)		
169.46	56.85	-2.37	250.84	81.20	-6.91
(6.16)	(2.87)	(0.67)	(6.16)	(3.05)	(1.36)
0	65.61	0	0	81.01	0
	(6.16)			(6.16)	
0	-38.89	15.27	0	-59.68	21.58
	(2.38)	(6.16)		(2.85)	(6.16)
SM1 (100xA^{-1})			**SM1R (100xA^{-1})**		
0.590	**-0.457**	0.091	0.399	**-0.306**	0.128
0	1.524	0	0	1.234	0
0	**3.880**	6.546	0	**3.414**	4.63

Table 9: Structural Parameters for the over-identified models with the Gini coefficient

SM1O (A)			SM1RO (A)		
167.46	50.22	0	238.88	59.12	0
(6.16)	(2.93)		(6.16)	(2.83)	
0	65.61	0	0	81.01	0
	(6.16)			(6.16)	
0	-38.89	15.27	0	-59.68	21.58
	(2.38)	(6.16)		(2.85)	(6.16)
SM1O (100xA^{-1})			**SM1RO (100xA^{-1})**		
0.597	**-0.457**	0.091	0.419	**-0.305**	0
0	1.524	0	0	1.234	0

[19] Since B is an identity matrix this is the same as A^{-1}.
[20] For instance, in the model identified as SM1RO, "S" stands for SVAR, "M1" for a M1 type model in terms of variables, "R" for a Near-VAR, and finally "O" because we have changed equations (7), (8) and (9) describing the errors of the model according to the restrictions imposed on the coefficients and the model is now over-identified.

0	**3.880**	6.546	0	**3.414**	4.634

Table 10 presents the results for the VAR and SVAR models that use the ratio *Q*_10_90 as the inequality measure. These results correspond to the over-identified models, respectively SM2O and SM2R1O, since for both VAR and SVAR models the *t*-values for the coefficients $a_{1,2}$ and $a_{1,3}$ are quite small and it was not possible to reject the null hypothesis that a_{12} and a_{13} are both equal to zero (the results of the LR test of the joint restriction are, respectively, $\chi^2(1)=3.746$ and 4.160). As we can see, both a distribution shock[21] and a human capital shock have no impact on output. As before however, a distribution shock has a negative impact on education so that less inequality (now corresponding to a rise in *Q*_10_90) leads to less education. Our previous idea[22] that the credits markets imperfection channel might be a relevant mechanism to explain the influence of inequality on output in the Portuguese economy is thus not confirmed.

Table 10: Structural Parameters for the over-identified models with *Q_10_90*

SM2O (A)			SM2RO (A)		
132.75	0	0	203.52	0	0
(6.16)			(6.16)	(2.83)	
0	54.57	0	0	82.15	0
	(6.16)			(6.16)	
0	47.30	26.96	0	81.68	46.80
	(3.22)	(6.16)		(3.54)	(6.16)
SM2O (100xA^{-1})			**SM2RO (100xA^{-1})**		
0.753	**0**	0	0.491	**0**	0
0	1.832	0	0	1.217	0
0	**-3.215**	3.709	0	**-2.125**	2.137

Table 11 presents the results for the VAR and Near-VAR models, M3 and M3R, respectively that consider *Q_25_90* as the inequality measure, with some additional restrictions. For both VAR and SVAR models the *t*-values of the coefficients $a_{1,2}$ and $a_{2,3}$ are quite small but it was possible to reject the null hypothesis that $a_{1,2}$ and $a_{2,3}$ are both equal to zero at the 1.6% and 0.5% levels of significance for the VAR and the Near-VAR models, respectively. Since the restriction that $a_{1,3}$ alone equals zero is not

[21] Recall that when measuring inequality using the ratios *Q*_10_90 and *Q*_25_90, it is a decrease in either that corresponds to more inequality, contrary to what happens when using the Gini coefficient as the inequality measure. Thus the relevant estimated coefficients should have opposite signs in these cases in order to allow us to reach the same conclusion on the growth impact of inequality.
[22] See the analysis of Table 4.

rejected (the results of the LR test of the joint restriction are, respectively, $\chi^2(1)$=1.951 and 2.150, respectively), we estimate the corresponding SM3O and SM3RO over-identified models. These results are presented in Table 11. The coefficient estimates show a negative impact of a distribution shock on output and a positive one on education, confirming the results obtained with the Gini coefficient (see Tables 8 and 9). The first result seems to confirm our previous idea that the fiscal channel is a relevant mechanism to explain the influence of inequality on output in the Portuguese economy

Table 11: Structural Parameters for the over-identified models with *Q_25_90*

SM3O (A)			SM3RO (A)		
176.01	-27.96	0	294.41	-51.05	0
(6.16)	(2.51)		(6.16)	(2.87)	
0	44.37	0	0	68.62	0
	(6.16)			(6.16)	
0	47.84	25.42	0	84.85	43.31
	(3.74)	(6.16)		(4.07)	(6.16)
SM3O (100xA^{-1})			**SM3RO (100xA^{-1})**		
0.568	**0.358**	->0	0.340	**0.253**	->0
0	2.254	->0	0	1.217	->0
0	**-4.241**	3.934	0	**-2.125**	2.310

Notes: '->0' stands for infinitesimal values.

From the estimation of the SVAR models with the different inequality measures it is possible to highlight two results. A distribution shock corresponding to an increase in inequality has a negative impact on output (except for the models that use the *Q*_10_90 ratio) and has a positive impact on education. The latter result indicates that inequality can be considered as a premium on education: at the individual level more earnings inequality means a higher opportunity cost of the no(more)-education decision. The rationale for the first result might lie in the corrective policy measures aimed at reducing the rise in inequality that will influence decisions affecting labour supply[23] and reducing investment, since they are most likely financed by taxes with the associated distortionary effects. However, the results also point to a non-negative impact of education on output, as predicted by economic theory. We thus have to reconcile the results of a positive effect of inequality on education and this non-negative effect of education on output with the result of a negative effect of inequality on output. In order

[23] For instance, individuals/workers will not invest as much in human capital since they will expect higher income taxes.

to get an idea of the global impact of inequality on output, the main goal of this paper, we conducted an impulse response analysis since it takes into consideration the interactions between all the variables.

Impulse response analysis based on the Near-VAR and SVAR modelling

The impulse response analysis shows how a one standard deviation innovation in one of the variables of the model affects the contemporaneous and future values of all endogenous variables in that same model. In Figures 1 and 2 we present the impulse response functions for the Near-VAR model M3R and for the structural version of model M3, model M3RO[24]. Both models use *Q_25_90* as the inequality measure.[25]. We only describe and analyze the results for model M3RO (Figure 2) since the results of the impulse response functions analysis are not substantially different across the two models.

The main results concerning the impact of each of the three possible structural shocks are:

a. a supply shock has: (i) a persistent positive impact on output, as expected; (ii) a negative impact on earnings inequality (*Q*_25_90 rises so there is less inequality) – according to the lower confidence interval (c.i.) this effect vanishes after 3 years but the response values shows that there is still a reduction in inequality 9 years after the shock; (iii) a negative effect on the level of education during 1 to 3 years, but after 8 years there it has an unambiguous positive effect[26];
b. a distribution shock, corresponding to a reduction in inequality, has: (i) a clearly positive effect on output for at least 8 years; (ii) a positive impact on *Q*_25_90 (inequality decreases) that vanishes right after 2-2.5 years; (iii) a negative impact on education during the first year, followed by a null effect (see the lower c.i.), but after 6 years it becomes positive and remains so for the next 4-5 years, which is probably a consequence of the effect of the distribution shock on output;
c. a human capital shock has: (i) a clearly positive impact on output during the first 4 years becoming null afterwards (see the lower c.i.); (ii) a clearly negative impact on *Q*_25_90 (inequality increases) during the 2 first years, and after a null effect

[24] See Table 4 for the Schwarz criterion results.
[25] The 90% confidence intervals correspond to Hall's percentile interval calculated with 100 bootstrap replications ((Hall 1992)).
[26] We are convinced that the effect of the supply shock on inequality (a decrease) is responsible for the negative effect on education on impact.

during the third year, the effect becomes negative again for the next 6-7 years. The persistence of this human capital shock on education is obviously important, lasting for as long as 9 years, even though, as time goes by, the quantitative impact becomes much lower than the initial impact.

Figure 1: Responses to supply, inequality and human capital shocks in model M3R

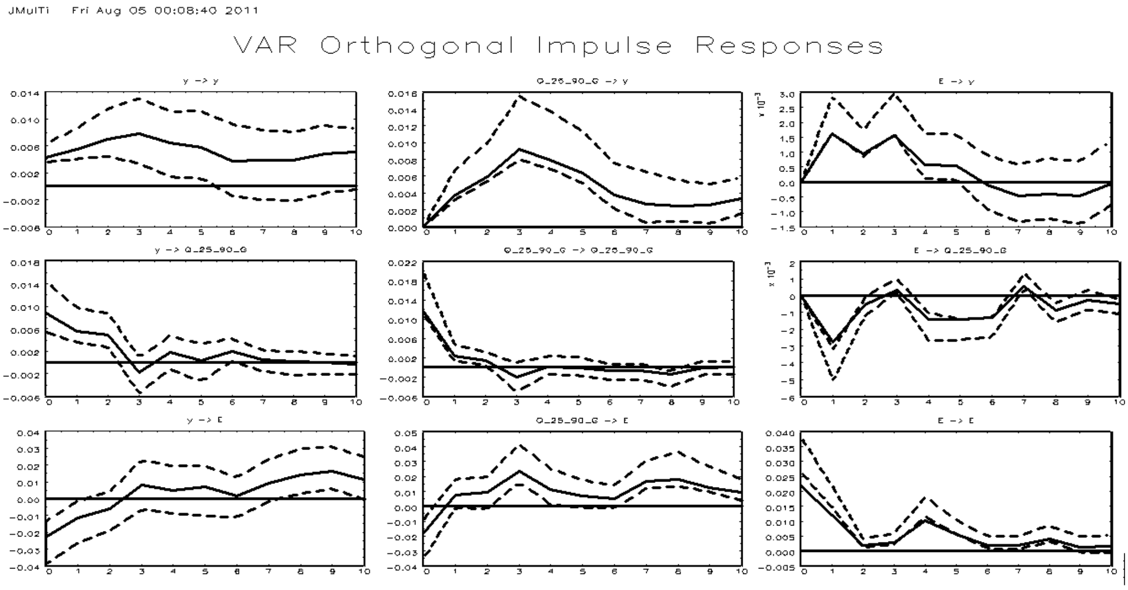
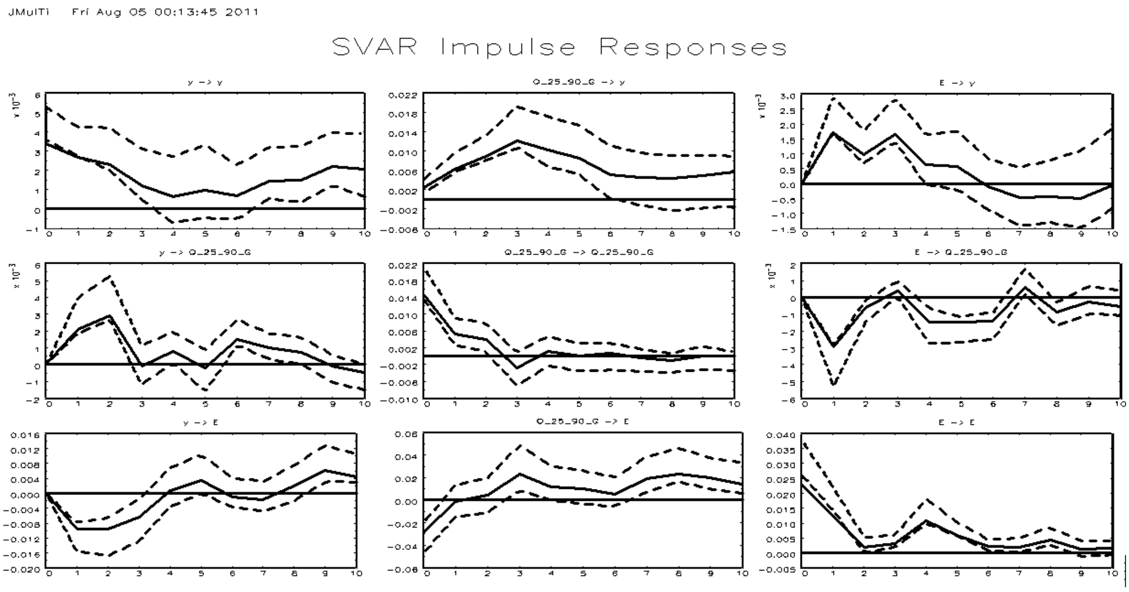


Figure 2: Responses to supply, inequality and human capital shocks in model SM3RO



4. Conclusions

This study examined the impact of earnings inequality on output in Portugal in order to contribute to the ongoing debate on the impact of inequality on economic growth. To achieve this goal we conducted a time series analysis of the relationship between output, earnings inequality and education over the period 1985-2007, using different econometric methodologies: the Hendry-Krolzig general-to-specific reduction methodology; VAR and Near-VAR modeling; Granger and instantaneous causality; and the structural VAR approach with the associated impulse response analysis.

The results suggest that earnings inequality has a negative impact on output supporting in this way the view that inequality is detrimental to growth. This result does not seem to depend on the time series methodology applied. For instance, the long-run equation for output, obtained with the Hendry-Krolzig general-to-specific reduction methodology shows a negative relationship between earnings inequality and output. Additionally, the VAR and Near-VAR analysis indicates that there is a high level of interdependency among the three variables in our models, output, earnings inequality and education.

The analysis based on the corresponding structural models (SVAR analysis), found that in the models with the Gini coefficient and the *Q*_25_90 ratio there is a negative relationship between distribution shocks (increased inequality) and output and a positive relationship between distribution shocks and education. Only the latter conclusion applies in the model with *Q*_10_90. Finally, taking into account the interdependency between the variables by analyzing the respective impulse response functions, we confirmed the negative effect of a distribution shock (increased inequality) on output and a long run positive effect of a distribution shock on education. As for the direction of causality, this seems to run mainly from inequality to growth and not the other way around.

As far as education is concerned, the evidence does not support the theoretical prediction that more inequality reduces human capital accumulation, pointing in fact in the opposite direction: an increase in earnings inequality, corresponding in our models to a distribution shock, results in more educated workers, an indication that inequality acts as an incentive for individuals to belong to the richer parts of society, which can only be achieved by investing in human capital.

In summary, the results obtained point to a negative global influence of inequality on output, that however does not seem to be explained by the prediction of the credits markets imperfections channel which argues that more inequality leads to less human capital accumulation and thus slower growth. Our preferred explanation for this negative impact is thus that suggested by the fiscal policy channel: more inequality implies more redistribution, with the associated distortionary effects from taxes on investment. Corrective policy measures aimed at reducing the rise in inequality may thus influence decisions that will affect, in a negative way, investment and production opportunities.

Further research, as more data becomes available, should focus on extending the time period analyzed and considering alternative inequality measures relative to the distribution of income or the distribution of education.

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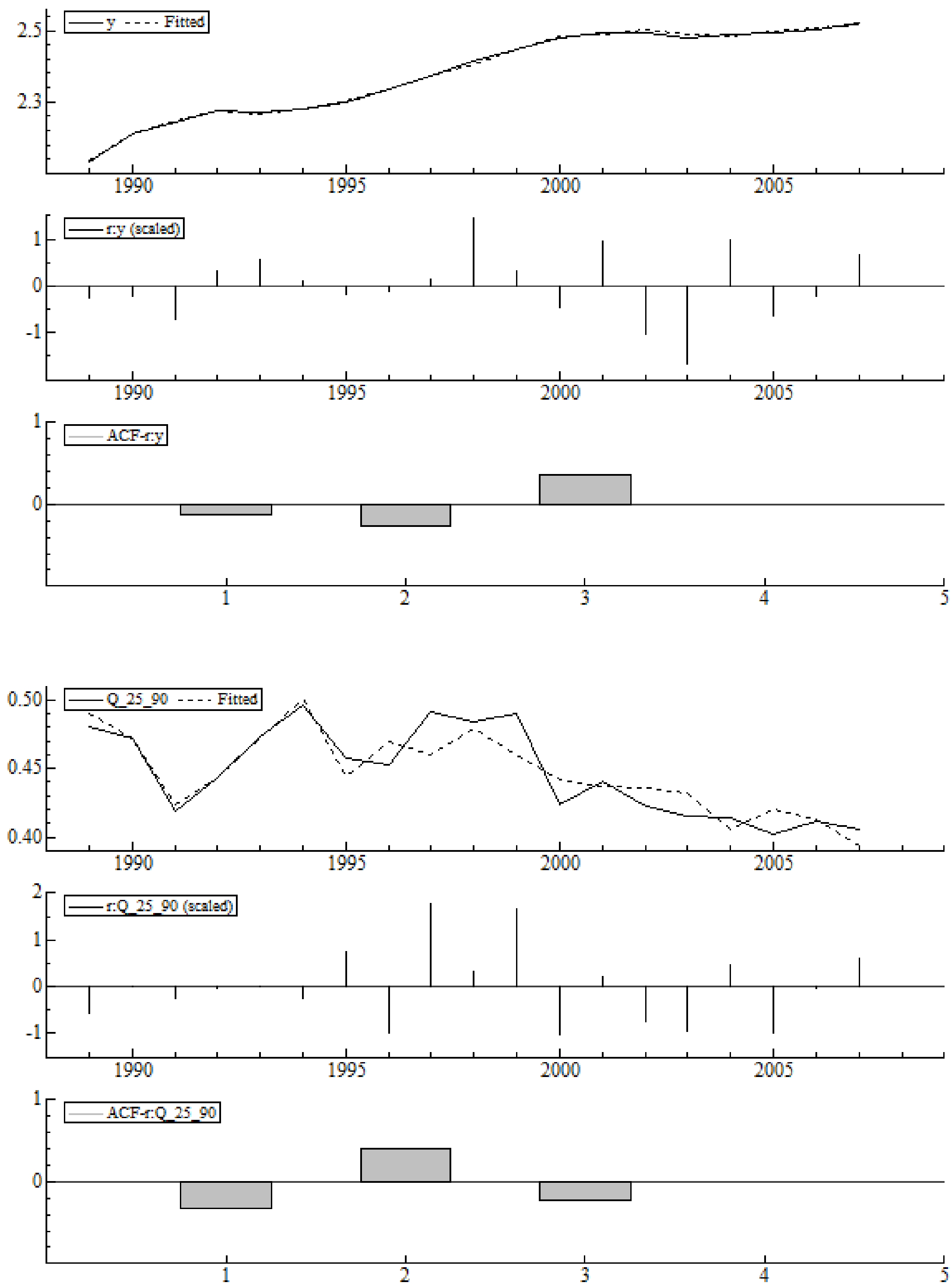
Appendix

Figure A1: Fitted values, scaled residuals and ACF for residuals for the Near-VAR model M3R



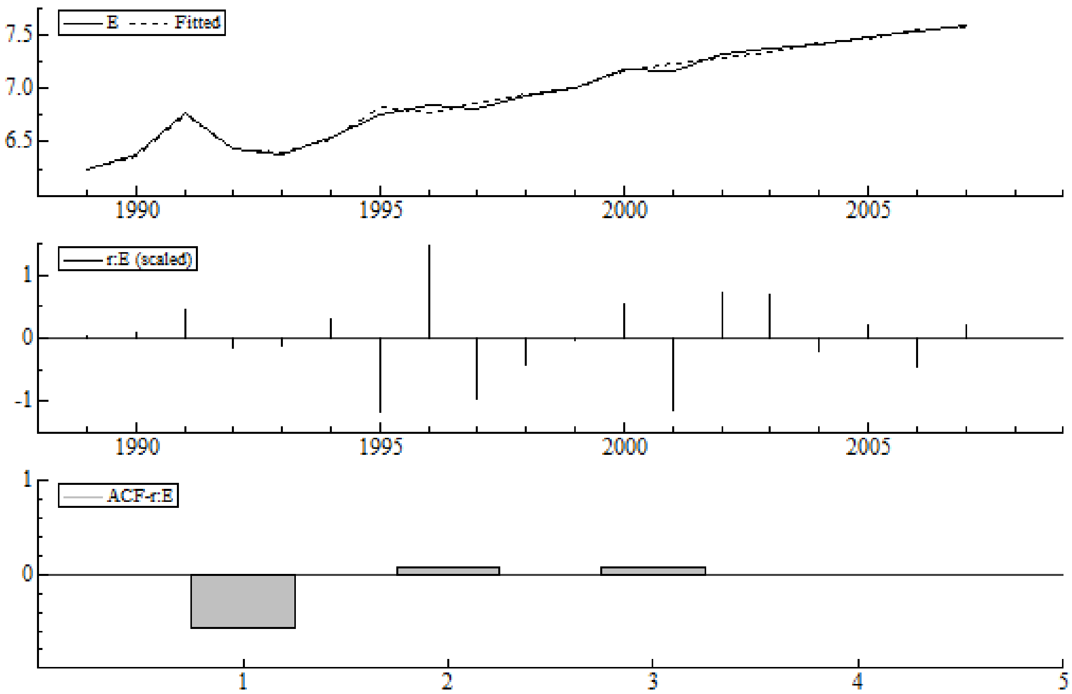
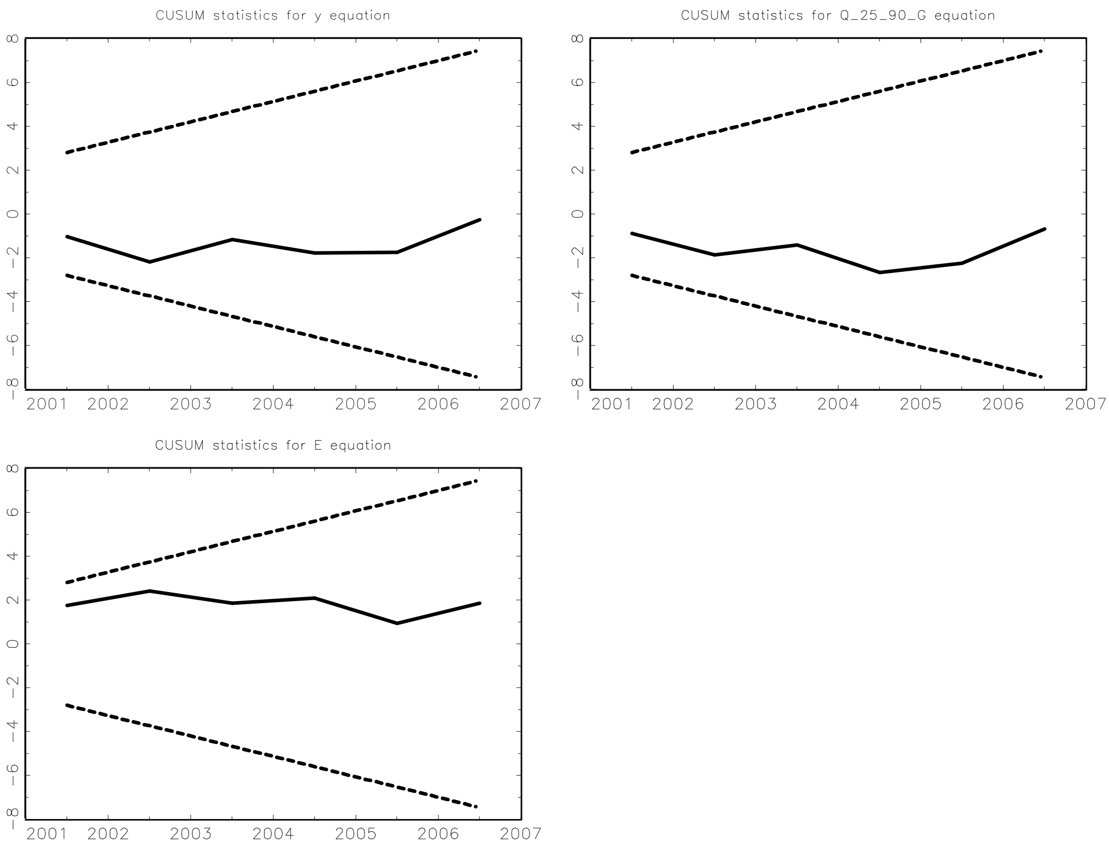


Figure A2: OLS-CUSUM test results for model M3R at 1% significance level



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