Nationalekonomiska Institutionen

Lunds Universitet

An econometric analysis of the relationship between inequality and growth

Master's thesis
Author: Dag Lyberg
Tutors: Kristian Jönsson
and Joakim Westerlund
Date: June 2006

Abstract

In this paper, the role of inequality in growth economics is investigated. Barro (2000) found a positive interaction between inequality and GDP on the growth rate, using data for 1960-2000. This paper focuses on a robustness check of his results due to a revision of the Ginis from Deininger and Squire (1997) in the WIID2 dataset. My regressions cover the same time periods and include additional data from the Fraser Institute in line with the theories proposed by Barro. The findings are: When not controlling for fertility, (1) a lower degree of income inequality enhances growth, therefore reducing inequality increases growth and (2) there is a positive interaction between income dispersion and GDP on growth, thus more inequality increases growth in rich countries and reduces growth in poor countries. When controlling for fertility, (3) the relationship between inequality and growth disappears altogether. Unlike Barro, I find that income inequality is only significant if fertility is absent. Thus, reducing child birth is the key to higher growth.

Table of Contents

1. Introduction

This paper examines the relationship between income dispersion and growth, which is a large area in development economics. The first modern economic paper on this issue was written by Kuznets (1955), who introduced some theory and speculation as to what the determinants are; but, largely owing to lack of data, which was not unusual of his time, he provides little statistical evidence. Since then, a vast array of papers have been produced, and most of them concentrate on two questions: is there a relationship between growth and inequality? If there is one, then what is the mechanism behind it and how large is it?

Kuznets introduced the so-called inverted U-curve. It states that a poor country has a low degree of inequality initially, but as some people move into high-wage sectors, inequality is increasing. Later on when few are left in the low-wage sectors, inequality is reduced. Extending the same model globally, poor countries should be growing more quickly than rich countries; otherwise, their standards of living are not converging.

The relationship between income dispersion and growth is interesting and important, because some countries have been growing more quickly in the last few hundred years. As some countries are rich and others poor, it raises the question what the drivers of growth are. Theories can explain part of this relationship and a good amount of literature on this topic has been produced, but many questions remain unanswered.

Barro (2000) investigated the connection between inequality and growth covering 1960-2000. His conclusion was that a higher degree of inequality reduces growth in poor countries, but increases it in rich countries. This holds after controlling for political and economic factors. He provides some regression results that he claims to back his answer. Other authors that have produced papers on this topic are Alesina and Rodrick (1994) and Perotti (1992).

My paper focuses on a robustness check of Barro's paper. The question is: how robust are Barro's regression results? This paper attempts to answer three questions:

- Are Barro's results reproducible?
- Does the addition of control variables based on data from the Fraser Institute would produce a different response?
- Barro (2000, p. 17) reported that the inclusion fertility renders the coefficient on Gini insignificant in one regression. Does inclusion or omission of fertility variable produce the same result if repeating the process?

My regressions first attempt to reproduce Barro's results, and then add the additional variables to see if the results still hold or are different. I use 2SLS and White and MacKinnon's robust estimator rather than 3SLS in Barro's case, do not include time dummies, and use dummies for Africa and Latin America rather than colonial status. The sample size is smaller but the results seem consistent throughout the regressions.

This paper contains the following sections: Section 2 gives a short introduction to theories related to growth theory, and to the previous works by Barro (1991 and 2000), Alesina and Rodrick (1994) and Perotti (1992). Section 3 introduces the econometric models to be used in my regressions, and econometric problems. Section 4 gives an account of both the focus and control variables. Section 5 presents the econometric results and section 6 an analysis thereof. The final section concludes for the whole paper and the regressions can be found last.

2. Theory

In this chapter, I will introduce the work on inequality and growth of previous authors and their results. Finally, focus shifts to the theories that are related to inequality that are important in the choice of control variables.

2.1 Inequality and growth

Kuznets (1955) was the first in his field to introduce the idea that income dispersion would affect growth. His thesis was that, initially, when a country is undergoing growth due to high growth rates in new economic sectors (intra-industry growth), income dispersion, i.e. inequality, widens. He was referring to industrialisation when people were leaving old occupations in the agricultural sector and entering new ones in urban industries, moving up the wage ladder. The proportion of the rich is small in the beginning. As more people are moving into higher-wage sectors, income dispersion will narrow. China is a good modern example of this model: industrialisation along the coast, where wages and the standard of living is higher, has attracted people from the agricultural sector from the interior. Average income has increased, but so has income dispersion. China has not yet entered the phase of narrowing income dispersion, but it may do so in the future. This theory predicting a rise in income inequality in the beginning of a change in economic sectors and then a fall in income inequality towards the end is referred to as Kuznets' inverted U-curve, or Kuznets' U-curve for short.

Kuznets did not possess the data for empirical backing of his theory, since macroeconomic data were scant. His contribution was theory rather than proof. Recent contributions on income dispersion and growth have been produced by Alesina and Rodrick (1994), Perotti (1992) and Barro (2000).

Romer (2005) created a list of some theories by other authors that attempts to explain economic growth as a result of institutional factors. First, geographic location is a strong determinant: vicinity to the equator is associated with a lower GDP per capita than countries with a temperate climate. Causative factors could be disease and less fertile earth for agriculture. Though this is statistically correct, it may be a false conclusion in his view. Romer goes on arguing that social infrastructure offers a better explanation, as tropical countries have badly developed institutions. This can be explained by colonisation, which aimed at extracting resources and using cheap labour, thus not supporting institutional development.

It might be difficult separating institutions from geography. Romer used former colonies such as the USA, New Zealand, Australia, Singapore and Hong Kong as an example claiming that these states had a greater proportion of Europeans to develop institutions. This had a positive effect on economic development.

2.1.1 Barro

Barro (1991) does not investigate the role of inequality on growth, but his work is very empirical and he uses much of his own data (the Barro-Lee dataset) in his 2000 paper. Here, he uses the ordinary least squares (OLS) framework with White's robust estimators to find the determinants of growth. The important factors are the initial level of GDP, human capital, government expenditure, social stability, inflation and geographic location.

Barro (2000) investigated the question of income inequality. His conclusions were that income inequality had a negative effect on growth for countries with a low initial level of GDP but a positive effect for countries with a high level of GDP (Barro, 2000, p. 20-21). This is an important result. It means that inequality alone is not important but rather in combination with other factors, of which the current level of standard of living is most important. In my view, this suggests that poor countries should be aiming at creating an even level of welfare, whereas rich countries should be aiming at creating an uneven level of welfare, provided that GDP growth is the target. Another result is that there is support for the Kuznets curve. After controlling for the level of income dispersion, rich countries are growing more slowly than poor countries, resulting in convergence of countries' standard of living. This supports the convergence criterion as predicted by the Solow-Swan model.

2.1.2 Alesina and Rodrick

Alesina and Rodrik (1994) constructed a model on economic growth and inequality, in which there is an initial income or wealth distribution that should be taken as given. Economic agents are not homogeneous in terms of productivity and wealth. The government taxes the private sector and provides public utilities to the population. There is only one type of output and everyone benefits from government expenditure. The voting process determines the direction of policy and therefore the amount of government expenditure and taxation. A higher tax rate benefits low-income earners more than high-income earners, but, within the framework of the Laffer curve, there is a tax rate above which growth is lower than maximum.

This model implies that elections and influence in the political process are important determinants of economic growth. In unequal societies, the median voter has an income that is lower than that of the mean and will prefer higher taxes, resulting in lower growth[1]. Likewise, low-tax countries will have higher growth rates. Since an equal income dispersion lessens the need of taxation for perceived egalitarianism, they will have lower taxes and therefore higher growth.

Alesina and Rodrik (1994) give some econometric evidence that back their theory. The conclusion is that more unequal distribution of income and land leads to lower growth per capita.

2.1.3 Perotti

Perotti (1992) represents a similar idea but is more specific about the function of income dispersion. What is important is not only the distance between rich and poor, but also the position of the middle classes between the two others. Think of the political process as an inter-temporal expenditure choice by the consumer. In a poor economy, only high-income earners can invest in human capital, economic growth will subsequently occur and there will be more resources available to distribute than if there had not been any investment. In the first time period, the median voter may have to abstain from material welfare to accept investment. Therefore, the choice is between uneven consumption that is higher on average or an even consumption that is lower on average.

To poor economies, there are two requirements: firstly, the absolute income level of the top-earners should be high enough to allow them to invest; and secondly, the middle-classes should be in sufficient proximity to the upper-classes so that they do not prefer excessive taxation that will, in turn, prevent investment into education.

In rich economies, the requirements are the opposite to those of poor economies. High growth rates will occur if low-income earners invest into education. Thus, we require that the absolute income level of low-income earners should be high enough to allow for investment, and the middle-classes should be in sufficient proximity to the lower-income classes, or else the cost of income redistribution will exceed the gain from investment into education by low-income earners. Therefore, high-income countries are likely to result in excessive taxation and income redistribution if the median voter prefers current consumption to future consumption.

There are many theories that are relevant in the inequality-growth relationship. Alesina and Rodrik's theory is relevant to democratic states and belongs to the branch of political economy; Perotti's idea seems to be referring directly to the inequality-growth relationship, but even here he is ignoring many

---

1 Since voting was mentioned above, the immediate association is often that this would describe a political situation that is unique to Western democracies. This is not always the source of influence. Nevertheless, inequality could still have influence in development of any country.

other factors and is not very precise about the mechanism within the inequality-growth relationship.

Perotti (1992) mentions that his results support the theory that the income share of the middle classes affects economic growth, but published no statistical evidence.

2.2 Theoretical effects of inequality on growth and investment

I introduce the theoretical effects on growth of each theory and the direction of growth given an increase in these factors. These explanations are essential, since they govern the choice of control variables.

Barro's range of control variables is limited. He includes factors that are related to political and economic events, but the coverage of the business environment and many macroeconomic factors is missing, in my opinion. For example, I have included two additional variables to the theory of credit-market imperfections, one to political economy, and one dealing with both sociopolitical unrest and credit-market imperfections.

He outlined four relevant theories in the inequality-growth relationship: credit-market imperfections, political economy, sociopolitical unrest and saving rate. This is a good theoretical coverage of the inequality-growth relationship. Most authors just mention the beginning (inequality) and the end (GDP growth). A better depiction of the causal relationship based on Barro's (2000) paper is shown in equation (1):

$$\text{Inequality} \rightarrow \text{Investment} \rightarrow \text{Growth} \qquad (1)$$

As is clear, inequality determines investment and, in turn, economic growth results from investment. The role of investment could just as well be investigated, but this approach will not be pursued here, since it appears implicitly in the inequality-growth relationship.

This paper is dedicated to a robustness check of Barro's (2000) paper. The choice of relevant control variables in my regressions are based on the four theories. They are outlined below.

2.2.1 Credit-market imperfections

A reduced ability to borrow money means that the private return to investment is dissimilar to the public return to investment. This could result from imperfections in the credit market such as asymmetric information and limitations of legal institutions, leading to investors being unwilling to lend if they cannot collect interest to the return of investment, for instance owing to the absence of a legal framework, bad implementation of bankruptcy laws or because of the absence of liquidity.

For poor households, the private return to investment of education may be lower than the social return to investment. Therefore, they fail to take advantage of investment into education and subsequent growth opportunities. A redistribution of income from rich to poor may help to raise growth and reduce income inequality initially. On the other hand when investment is bulky and requires fixed investment, we might require investment above a minimum threshold[2]. For example, secondary education may pay a better return than primary education.

Education is a proxy variable for human capital. It is an important input to many sectors, usually productive ones that require high levels of physical capital and have a high rate of technological progress. A country with a high level of human capital is better at importing knowledge from abroad through trade. The greater the ability in a country to diffuse existing technology from the technological leader will result in it growing faster (Barro, 1991, p. 409).

2 Barro (2000) reports that secondary and higher education of males is most important. In his 2000 paper (p.13), primary education of both sexes, and secondary and higher education of females are hold to be insignificant to growth. In his 1991 paper (p. 416), the coefficient on enrollment rates of secondary education is greater than that of primary education, suggesting that secondary education has a greater effect.

Credit-market imperfections are expected to reduce growth and education is expected to enhance it; secondary and higher education are probably more important than primary education[3]. For this theory, Barro (2000) used variables on the inflation rate, schooling and the fertility rate. My additional variables cover access to sound money and credit market regulations, both of which affect liquidity.

2.2.2 Political economy

The government is important for the economy in various ways. For example, courts and the police uphold the law and are requirements for a functioning society governed by rules. The government also invests in public infrastructure that allows transportation of goods and people. Some level of government expenditure is therefore positive. However, government expenditure requires government revenue and higher taxes. Too high a level of taxation suppresses the private return to investment below the level of public return, reducing future investment. More government expenditure is only expected to be positive to growth up to a certain level and this is represented by the Laffer curve (Laffer, p. 4).

The other side of the coin to government expenditure is government revenue, since all expenditure must be matched one-for-one either by loans or by taxation (the government can make additional revenue gains through unexpected inflation, withheld taxes, etc.; this enters rather the theory of credit-market imperfections). The effects on growth construed by the size of government can also be met with the measurements on taxation.

Barro (2000) includes a variable on government expenditure. I have included a variable on the highest marginal tax, since it is thought to affect the willingness to invest negatively.

I expect the sign of a cofficient on the size of government to be negative, since a larger size of government may reduce growth. This holds for both expenditure and taxes.

2.2.3 Sociopolitical unrest

Sociopolitical unrest can be further divided into two additional subgroups: quality of the business environment and political unrest.

The quality of the business environment cannot be objectively measured like openness and GDP accounts, since such measurements are subjective. To the extent that it can be measured, it is assumed to have a positive effect on GDP growth, since it allows businesses to invest into physical and human capital. Business environment refers to institutional factors, within which firms are operating. Firms prefer a stable and predictable environment in order to obtain a safe return to investment and less predictability is therefore likely to reduce firms' willingness to undertake it. Relevant factors are the legal system (enforcement and implementation of laws) and property rights (legislation).

Political stability is in a sense equivalent to the business environment, but referring to political rather than economic factors. It is assumed to suppress the willingness to invest and refers to factors such as war, assassinations, personal and civil freedom.

Barro (2000) has one variable on democracy and another one on the rule-of-law. I have included one that covers the efficiency of the legal system and protection of property rights. This lies closer to the business environment rather than the political system, as favoured by Barro.

I expect both the quality of a good business environment and political stability to enhance growth.

---

3 Regressions 1-7 in Barro (1991) do not give a conclusive result whether primary or secondary education is more important for growth. Testing for a difference greater than zero using a t test does not yield a statistically significant estimate in any of the regressions. However, Barro (2000, p.13) states on the other hand that secondary and higher education is significantly different from primary education. I find this to be plausible.

2.2.4 Saving rates

If investment is carried out by those on the top of the income distribution, income redistribution from rich to poor would reduce investment and thereby growth. In a closed economy without foreign direct investment and characterised by consumption and a low level of investment, income redistribution from poor to rich would in theory raise investment.

This view is in a way similar to the theory of credit-market imperfections. Openness is one of the keys to growth, especially if the goal is to catch up with the technological leader. Investment can take place through two ways: either through domestic investment or foreign investment. Foreign investment is further divided into indirect and direct investment. Foreign direct investment (FDI) has the advantage of not only increasing physical capital, but also increasing competition and importing human capital to the domestic work force. The last one contributes to so-called diffusion of ideas and technological spill-over effects. Thus, foreign investment is a way of transferring technology to less developed countries and may have a larger effect on those than in developed economies.

Foreign investment may also have the disadvantage that exposes a country to volatility in the financial markets. If investors fear that a country will give a lower rate of return in the future on assets in that country, then vast amounts of capital can be withdrawn in a short period of time and cause a financial crisis. The resultant effect is output to be below its optimal level.

Barro (2000) uses variables on investment and on terms of trade in his regressions. There is no additional variable by me.

Generally, saving rates are assumed to increase growth and openness is a proxy for FDI. I expect a positive sign on those coefficients that represent more domestic saving and openness.

2.3 Summary

The key weakness of Barro's (1991) and Alesina and Rodrik's (1994) econometric work is the coverage of a relatively short time period. The samples 1960-1985 and 1970-85 only allow for twenty five and fifteen years of cross-country data. Barro's (2000) paper covering 1960-2000, 40 years, is clearly an improvement since a longer time span better shows the long-term effect. Therefore, trends should emerge more clearly and be more robust to business cycle effects.

All authors seem to agree that inequality lowers growth after controlling for policy variables and geographic variables. This result is therefore consistent amongst these authors. However, as Perotti (1992) and Barro (2000) put forth, positive interaction between the degree of income dispersion within a country and a country's GDP level seems to be an important determinant.

Four important theories are identified by Barro (2000) that will be used in the theoretical framework in the choice of additional control variables.

3. Models

In this chapter, I will introduce the econometric models that are relevant in my paper. Specifically, emphasis is put on what theories are tested and what problems can arise and how they are solved in the regressions that are covered in standard literature on econometrics.

The centrepiece of Barro's (2000) paper is the concept of *conditional convergence*, also found in Mankiw, Romer and Weil (1992) and Barro (1991) and originating from the Solow-Swan model (Swan, 1956 and 1957), also referred to as the *neoclassical growth model*. It implies that technology is exogenously determined (outside of the model) and that the long-run level of growth rate is fixed and cannot be changed. However, there are other factors that have an influence on growth, but only in the short run through income that is saved and invested rather than consumed.

Growth is driven by productivity and there is no way to affect its growth rate. However, there are different ways to affect the importation of growth determinants, to import both technical and human capital, that in turn determine the potential output of an economy. It can be assumed that no country is ahead of the technological leader, e.g. the United States, and capital and know-how are imported through trade. Everyone can thus grow at the same speed as the technological leader, but none can overtake it.

The idea that government can affect the saving rate and investment into capital and human capital is an important idea, since it means that government affects the standard of living by means of policy and this justifies the inclusion of different variables, societal and governmental, that are included in my regressions.

An alternative growth model is the *endogenous growth model* (growth is determined inside of the model). It can be demonstrated in various ways and several different models exist. The uniting feature of this model is that it tries to model the origin of growth rather than taking it for granted. This requires an idea of how businesses operate and make decisions, i.e. it has microeconomic foundations at its core. The result of this is that countries that save more can grow at a higher rate indefinitely if they are spending more on investment, thus convergence may not result[4].

3.1 Regression procedure and the choice of two models

Barro (2000, p. 17) remarks that inclusion of fertility in his regressions causes the Gini coefficient to become insignificant. This raises the question whether there are two different models. I will have two models: one with fertility and one without.

His regressions looks as follows in (1). GINI represents the raw data on Gini and Gini*Log(GDP) (interaction variable of Gini and GDP), FERT log(fertility), INF inflation and CONTROL(1) are other control variables. My regressions look the same, and I add additional control variables (CONTROL2) from the Fraser Institute to (2) (except for INF; see above).

$$Y = GINI + FERT + INF + CONTROL(1) + ERROR \qquad (1)$$

$$Y = GINI + FERT + CONTROL(1) + CONTROL(2) + ERROR \qquad (2)$$

The first step in my regressions is to reproduce the results by Barro in (1). First this is done without GINI, then I add first Gini, then Gini and the interaction variable. I regress both controlling for fertility and without controlling for fertility. This adds up to five equations.

The second step is to add CONTROL(2), and there I try the four combinations of Gini only, Gini and the interaction variable; with and without FERT. In step (2), I have two samples of CONTROL(2) (see 3.3), which doubles the number of equations to 8.

4 Mankiw, Romer, Weil (1994), p. 421

3.2 Expected results

The basic question is whether the Gini and the interaction variable are significant or not. In the regressions where only Gini is present, significance of its coefficient means that inequality has an effect on growth. It is expected to have a negative effect. The t test is appropriate here. In the equations where both Gini and the interaction variable are present, the question is whether both are significant. If they are significant, then growth depends on both inequality itself and whether growth responds differently to inequality in rich and poor countries. The coefficient on the interaction variable is assumed to be positive. It is expected that inequality is good for growth in rich countries and bad in poor countries. Joint significance is tried by means of the Wald test. It is more powerful than the t test. Thus, if the result of the Wald test contradicts the result of two or more t tests, interpretation of the former takes precedence.

The fundamental matter is whether the inclusion of FERT and/or CONTROL(2) changes the significance of the Gini coefficients. If the individual significance of Gini or the joint significance of Gini and the interaction variable is rejected as described above, then inequality may not have an effect on growth since the inclusion of the control variables provide sufficient explanation on growth.

3.3 Econometric issues

There are many ways to carry out estimation. The commonest method is to use OLS. Because it relies on certain criteria specified in the Gauss-Markov assumptions, there are modifications that are based on OLS to address specific issues when those criteria are not satisfied. The extended models concerned are Generalised Least Squares (GLS) and Two-Stage Least Squares (2SLS, or TSLS).

In my regressions, I use a combination of 2SLS and GLS. My choice of estimation method should be similar to that of Barro (2000). The idea is to regress GDP growth on Gini and a group of control variables, which are the log GDP per capita and the square of it, government consumption, political instability, political rights and the square of it, years of schooling, the log of the total fertility rate, investment share of GDP and the growth rate of terms of trade.

I use a panel dataset of 10 year averages (1965-74, 1975-84 and 1985-94). The Ginis and the GDP level variables appear in the beginning of each period. All other variables are 10 year averages of these time periods.

In addition, because of using 2SLS, I need to specify the instrumental variables (IV). They are the present values of years of schooling and terms of trade; lagged values of all other variables[5]. The duration of the lag is five years between the IV and the endogenous variables. Years of schooling and terms of trade are starting in 1960, 1970 and 1980, and the other variables cover the periods 1960-69, 1970-79 and 1980-89.

My regression differ in a few respects to Barro. For example, I did not construct dummy IV on prior colonial status but used instead dummy IV on Africa and Latin America, which cover most former colonies. Second, when using my additional control variables from the Fraser Institute, I had to proxy the values of 1960-1969 using the average of 1970-1980. Third, I removed inflation as a variable after adding my control variables, the reason being that it is incorporated in the variable access to sound money.

3.3.1 OLS

OLS assumes that there are *n* observations and *k* variables in a system of linear equations. It can be

5 It is highly contradictory to use the past values of the log of fertility as an instrumental variable. Barro (2000, p. 12) gives the impression that the present values of fertility should instead be used. Upon attempting this, I obtained strong multicollinearity and low significance on most of my coefficients. Therefore, the past values make more sense as an instrument.

written as matrices in (3)[6]. Matrices express several linear equations in a very compact way. They are used for both coefficients and data. Mathematical operations like addition, subtraction, multiplication and division are possible. The advantage of using matrices is that they can show complex processes using very little space.

$$Y = X b + e \tag{3}$$

where Y is a vector of the dependent variable, X is a matrix of independent variables, b is a vector of coefficients and e is a vector of the residuals. Y and X are always given if the econometrician knows what he is looking for, but b and e are not. Since the coefficients in the b vector and the residuals in the e vector are unknown, they need to be estimated. OLS and Maximum Likelihood (ML) are two alternative methods. As ML is more complex, I will only be using OLS. The hat implies above the variables means that they are an estimator to separate them from the parameter value. Thus *b hat* is the estimated value, and b is the parameter value that is assumed to exist but is also unknown. The OLS estimator of b is:

$$\begin{aligned} \hat{b}_{OLS} &= (X'X)^{-1} X'Y \\ &= (X'X)^{-1} X'(Xb+e) \\ &= (X'X)^{-1} X'b + (X'X)^{-1} X'e \\ &= b + (X'X)^{-1} X'e \end{aligned} \tag{4}$$

$$E[b_{OLS}] = b ; E[X'e] = 0$$

The variance of $\hat{b}_{OLS}$ is :

$$\begin{aligned} VAR(\hat{b}) &= E[(\hat{b}-b)(\hat{b}-b)'] \\ &= E[((b+(X'X)^{-1}X'e)-b)((b+(X'X)^{-1}X'e)-b)'] \\ &= E[((X'X)^{-1}X'e)((X'X)^{-1}X'e)'] \\ &= E[((X'X)^{-1}X'e)(e'X(X'X)^{-1})] \\ &= (X'X)^{-1}X'E[ee']X(X'X)^{-1} \\ &= \sigma^2 (X'X)^{-1}X'X(X'X)^{-1} ; E[ee'] = \sigma^2 I_k \\ &= \sigma^2 (X'X)^{-1} \end{aligned} \tag{5}$$

The variance of the residuals, σ^2, is also unknown and must be estimated. The residuals are estimated as follows:

$$\hat{e} = Y - X\hat{b} \tag{6}$$

And the estimated variances of e is:

6 See Gujarati (2003, p. 926-948) and Judge et al. (1988, p. 329-331, 644-645) for all references to econometrics in this chapter.

$$
\begin{aligned}
VAR(\hat{e}) &= E[\hat{e}'\hat{e}] \\
&= E[(Y - X\hat{b})'(Y - X\hat{b})] \\
&= E[e'(I_n - X(X'X)^{-1}X)'(I_n - X(X'X)^{-1}X)e] \\
&= E[e'M'Me]; M = (I_n - X(X'X)^{-1}X) \\
&= E[e'Me]; M'M = M \\
&= tr\, M\, E[ee'] \\
&= tr[M * (\sigma^2 I_n)]; E[ee'] = \sigma^2 \\
&= \sigma^2 tr[I_n - X(X'X)^{-1}X'] \\
&= \sigma^2[tr(I_n) - tr(X(X'X)^{-1}X')] \\
&= \sigma^2[tr(I_n) - tr(X'X(X'X)^{-1})] \\
&= \sigma^2[tr(I_n) - tr(I_k)] \\
&= \sigma^2(n-k)
\end{aligned}
\tag{7}
$$

3.3.2 2SLS

In OLS as a model (not the estimation method), it is assumed that all variables in the X matrix are exogenous, that is they are determined outside of the model and bear no relation to each other or any other variable. The result is that there is no relation between X and e, and thus OLS produces unbiased estimators. If this does not hold, then the product of X and e will not be zero and X is said to be endogenous.

It is important to distinguish between the assumptions of the model and the results that appear with an estimator. They do not always hold. Using the OLS estimator (4), we obtain.

$$
\begin{aligned}
\hat{b}_{OLS} &= b + (X'X)^{-1}X'e \\
&\neq b \\
\lim_{n\to\infty} & E[b_{OLS}] \neq b; \lim_{n\to\infty}(X'e) \neq 0
\end{aligned}
\tag{8}
$$

It is clear from (8) that the OLS estimator is *biased*, since the error $(X'X)^{-1}X'e$ is present on the right hand side. Another expression is an *inconsistent* estimator, meaning that the error becomes remains as the sample size gets larger. This is conveyed in the expression $\lim_{n\to\infty}(X'e) \neq 0$. An estimator can be *consistent*, in which case the error disappears as the sample sizes gets larger. This holds if $\lim_{n\to\infty}(X'e) = 0$. The inconsistency property does not remove the error, but can reduce it.

Two-stage least squares (2SLS) is used when the error term and the independent variables are correlated. Assume that X is assumed to be closely related to another variable, Z, plus an error, v, shown in equation (9) below.

$$
X = Z + v \tag{9}
$$

The 2SLS estimator assumes that the bias can be removed from X if the variable Z is correlated with X but not with e. Z is called an IV. If we regress X on Z, we obtain an estimate of X, that is $\hat{X}$, which can be done by OLS regression as shown in (10).

$$
\begin{aligned}
\hat{X} &= Z(Z'Z)^{-1}Z'X \\
&= Z(Z'Z)^{-1}Z'(Z+v) \\
&= Z + Z(Z'Z)^{-1}Z'v
\end{aligned}
\tag{10}
$$

$$
\lim_{T\to\infty} E[\hat{X}] = X; \lim_{T\to\infty}(Z'v) = 0
$$

Because we have $\lim_{T\to\infty}(Z'v)=0$, we get $\lim_{T\to\infty}E[\hat{X}]=X$ and the estimator of X is consistent. If we substitute this variable into (4) for *X*, we should be able to also obtain a consistent value of the coefficient vector *b*. This is shown below in (11).

$$\begin{aligned}
\hat{b}_{IV} &= (\hat{X}\hat{X})^{-1}{}'\hat{X}'Y \\
&= (Z(Z'Z)^{-1}Z'X)'(Z(Z'Z)^{-1}Z'X)^{-1}(Z(Z'Z)^{-1}Z'X)'Y \\
&= ((X'Z(Z'Z)^{-1}Z')(Z(Z'Z)^{-1}Z'X))^{-1}(X'Z(Z'Z)^{-1}Z')'Y \\
&= (X'Z(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z')Y \\
&= (X'Z(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z')(Xb+e) \\
&= (X'Z(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z'X)b \\
&\quad +(X'Z(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z')e \\
&= b+(X'Z(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z')e
\end{aligned} \tag{11}$$

$$\lim_{T\to\infty}E[\hat{b}]=b\,;\lim_{T\to\infty}(Z'e)=0$$

Since $\lim_{T\to\infty}(Z'e)=0$ holds by assumption, the second term disappears and we get the consistent estimator $\lim_{T\to\infty}E[\hat{b}]=b$. This is a two-step procedure using OLS, hence the name 2SLS. The first step is to regress *X* on *Z* to obtain a consistent estimate of *X*, as shown in (10), and then to regress *Y* on this, as shown in (11).

This method works well provided that good IV can be found. If wrong or bad IV are found, then *Z* and *e* will be correlated and $\hat{b}_{IV}$ will remain biased. Using 2SLS would thus be counterproductive and another solution must be found.

It is hard to find good examples of IV in the textbooks on econometrics. Some examples from the papers are better. Alesina and Rodrick (1994) used dummies for Africa and Latin America in their regression, the argument being that the geographic position of countries has an effect on growth. It must not be to do with geography itself, but since many of these countries were colonies and inherited their institutions from the colonising countries, this might have had an effect on growth. Barro (2000) could be assumed to argue along this line as he used a dummy for prior colonial status for IV.

Because my regressions are based on those of Barro (2000), I use the same IV though substituting Africa and Latin America for prior colonial status. Apart from this, Barro considers the lagged values of the right hand side variables, except for the growth rate of terms of trade and years of education. He probably considered present values to be a consequence all lagged variables.

3.3.3 MacKinnon and White's robust estimator

One assumption behind OLS is that the residual term is constant. In the case of heteroskedasticity, the residual term has a non-constant variance. This causes problems to empirical testing when the variance is biased, the consequence being that t and F tests cannot be used. In (7), the expected variance of the residuals contains a unit matrix, *I*. Assume instead that it contains a matrix, *Ω*, whose diagonal does not have unit values:

$$E[ee']=\Omega \tag{12}$$

Thus we end with the estimated variance of *b*:

$$\begin{aligned} VAR(\hat{b}) &= E[(\hat{b}-b)(\hat{b}-b)'] \\ &= E[((b+(X'X)^{-1}X'e)-b)((b+(X'X)^{-1}X'e)-b)'] \\ &= E[((X'X)^{-1}X'e)((X'X)^{-1}X'e)'] \\ &= E[((X'X)^{-1}X'e)(e'X(X'X)^{-1})] \\ &= (X'X)^{-1}X'E[ee']X(X'X)^{-1} \\ &= (X'X)^{-1}X'\Omega X(X'X)^{-1}; E[ee']=\Omega \end{aligned} \tag{13}$$

The Ω term will cause a heteroskedastic variance, and the error will not go away as the sample size increases, thus it is biased and inconsistent.

Ω is an unknown parameter and must be estimated. Some proposals were produced by Horn, Horn and Duncan (1975), Hinkley (1977) and White (1980). The preferred method is by MacKinnon and White (1985)[7], whose estimator is:

$$\begin{aligned} &VAR(\hat{b}) = \frac{n}{(n-1)}(X'X)^{-1}[X'\Omega X - \frac{1}{n}(X'e*e*'X)](X'X)^{-1} \\ &\text{where } u_t^* = \hat{u}_t/(1-k_{tt}) \end{aligned} \tag{14}$$

Barro (2000) preferred 3SLS to deal with heteroskedasticity. I will use MacKinnon and White's (1985) method to correct for heteroskedasticity.

3.3.4 Heteroskedasticity-corrected 2SLS

There is no given abbreviation for the method that I will prefer to use, consisting of 2SLS and MacKinnon and White's heteroskedasticity-corrected variances. I will simply refer to it as *robust 2SLS* henceforth.

3.4 Other issues

I use two models, one with fertility and another one without it. In order to judge the quality of regressions both for nested and non-nested models, one can use adjusted R^2, Akaike Information Criterion (AIC) and Schwartz Information Criterion (SIC). AIC and SIC are the better ones to use and are not limited to nested models only. AIC is more sensitive than SIC and should only be used in small samples. My largest sample is 156 observations, which means that both will be useful. Since the same observations from the same dependent variable are required for a comparison, some regressions cannot be compared using AIC and SIC. t tests are used to check for individual significance of coefficients and the Wald test is used to check for the joint significance of two or more coefficients.

Checking for multicollinearity, heteroskedasticity and missing variables is useful but such features are not available in my statistical package (Gretl) for use with 2SLS, only OLS. Lastly, residuals should be normally distributed, or else t and F test cannot be used. The chi-square test of normality will be used for this purpose.

7 MacKinnon and White (1985) referred to the three methods as HC2, HC1 and HC3 respectively.

4. Data

Here, I show where the data were collected from, if they are raw data or transformed data, and qualitative aspects of them. A table of data characteristics is shown last in the paper.

Data can appear either in the form of original, unaltered variables, or in the form of constructed variables. The Gini index is the area between the 45 degree line and the Lorenz curve, which is the cumulative distribution function of income (in the case of income measurement). All of my variables are constructed using averages, logs, addition and subtraction. The GDP per capita variable, Ginis and years of schooling are the values in the beginning of each period, whereas all the other variables are ten year averages over the relevant time periods, as in Barro's (2000) paper.

4.1 Inequality

I have obtained data on Gini coefficients from the World Income Inequality Database 2 (WIID2), collected by United Nations University – World Institute for Development Economic Research (UNI-WIDER). It covers data for many countries all over the world and is the largest database of Ginis to date. The first data (version 1.0) were released in 2000, and an update (version 2.0) in June 2005.

The Gini index is a measure of inequality and dispersion of a countable quantity, say income or assets. It is often associated with measuring income inequality because of its wide use in this area. However, there are other indices, like the Theil and Atkinson indices. The income Gini index measures the distribution of income (i.e., income inequality), in which case we have, on the vertical axis of a graph, the distribution of population, and on the horizontal axis, income. The Gini index is the area between the 45 degree line and the Lorenz curve, which is the cumulative distribution function of income (in the case of income measurement). It has a finite distribution stretching from zero to one. It is widely used because of its simple mathematical properties, but there are other measures which put more emphasis on a part of the distribution (for instance, those at the bottom of the distribution), or groups that have other characteristics than income in order to compare within and between groups.

In *time series samples*, Ginis can be used to compare the evolution of income dispersion within a country over time, and, in *cross-country samples*, the state of income dispersion amongst countries at a point of time. A *panel dataset* is a combination of a time series and a cross-country sample. Thus, a group of countries can be compared over time.

Gini coefficients can be constructed in many different ways. The aim is to choose a definition that well reflects the *distribution of standards of living*. Another concern is that of consistency: the Gini coefficients should be *consistent over time* (the Ginis of one country should be comparable with other Ginis), and *consistent at a point of time* (the Ginis should be comparable across countries). If the goals of consistency and measurement accuracy are not satisfied, the Gini coefficients will be biased and this will pose a problem to the regressions in the next chapter.

There is no given standard of constructing income distribution data unlike those on national accounts. For instance, classification of trade items allows comparison of trends between countries. There are three conceptual issues that I deem as being important: first, each definition will yield a unique set of estimates and it is therefore important that a similar definition of characteristics be chosen. Second, the estimates are supposed to reflect similar properties in similar countries. For example, in non-monetary societies, it would be inappropriate to use income as a variable of wealth if people are frequently involved in barter; alternatively, salaries may be paid in kind. In both cases, their monetary income would be zero and the lesson is that consumption may be a better estimator than income. In industrialised countries, we might prefer net income or disposable income to gross income, as the we are interested in the purchasing power of individuals. Here, monetary income is more relevant.

Generally, I have chosen my sample of countries on the following characteristics (WIID v. 2.0a):

- *Income definition* is income of various kinds, or expenditure that measure the standard of living of people.
  - Industrialised countries should have *disposable income* as the definition of income, which is defined as total income plus transfers (social contribution and taxes), as I assume that this might better reflect the purchasing power of the population, as markets of goods and services in developed economies are monetised in the formal sector. Thus, a large infomal sector may make data on consumption preferable. Data on income, both salaries and other incomes, are also easy to collect in my view since they are available to the tax authorities. Two drawbacks are that income is more variable and consumption less (Deaton and Zaidi, 2002), and it requires definitions and observation of purchases of goods and services (Atkinson and Bourguignion, 2000). It can also be interesting to collect both and compare them, since both give different answers to the economist. Barro (2000, p. 21) reports that in his regressions, data on net income and expenditure give a significantly lower estimate than data on gross income. This arises due to the income redistributive effect of taxes and the lower volatility of expenditure.
  - Especially in agricultural countries, *expenditure* may be better measurement. Therefore, I have chosen this for some African and Latin American countries where appropriate. Aggregate consumption could cover food consumption, non-food consumption (clothing, education, transport, etc.), durable goods and housing expenditure.
- *Income sharing units* are used to make sure that the income or consumption being measured reflects the same people.
  - The order of preference is the *household*, then the *family* and lastly the *individual*.
  - On problem associated with this is the definition of the household and family since it will affect the estimates.
- The *Unit of analysis* is chosen to take reflect the relative need of each household and family.
  - *Equivalence scale* (OECD scale or Modified OECD scale) is preferred, which takes account of both children and adults but gives more weight to adults.
  - Otherwise I have preferred, second, *household* and, third, *family*.
- *Coverage* concerns the people who appear in the sample, i.e. the sample subjects. A larger share of the population, area, and ages is preferable.
  - As large share of the *population* as possible (otherwise, *taxpayers* or *income recipients*).
  - As large share of the *area* as possible (otherwise *urban*, then *rural*).
  - As many people of all *ages* as possible.
- *Quality*
  - In the WIID2 sample, each Gini has an estimate of the *sample quality*. High quality observations were selected when possible. This is important because it gives a good view of how well a Gini may reflect the distribution of standards of living (depending on the income definition) in a country and makes the whole task easier of selecting appropriate observations for the regression sample. The authors of the WIID2 report state that many Ginis had been wrongly labelled "good quality estimates" in the Deininger and Squire 1997 collection. Those Ginis were preferred by Barro (2000, p. 14) and this would introduce a bias.
  - The conditions for grading in the WIID2 collection are different from those in Deininger and Squire 1997. The purpose is to better reflect "survey quality and income concepts" (WIID2, p. 13). Therefore, apart from the mistakes committed by Deininger and Squire, there is a second source of alteration that could distinguish my choice of Ginis from those of Barro.

Altogether, there are 209 Ginis in my sample.

4.2 Credit-market imperfections

An effort was made to fit variables into the different theories explained by Barro (2000, p. 5-8). This holds for credit-market imperfections, political economy, sociopolitical unrest and saving rates. Suitable variables here are education, inflation, access to sound money and credit market regulation, fertility and terms of trade.

Education variables are a measure of the average number of years attained in different levels of education (primary, secondary and higher). These data were collected from the Barro-Lee dataset. They are available for both males and females separately and both genders, at ages above 15 and 25 years respectively.

Inflation was constructed from data on the PPP price level from the Heston-Summers dataset.

Access to sound money is a variable that grades the performance of countries according to different criteria and is available from the Fraser Institute. The criteria are a combination of the average annual growth of the money supply, variability of inflation, the recent inflation rate and a subjective measure of freedom to own foreign currency bank accounts domestically and abroad.

Credit market regulation is also from the Fraser Institute containing subjective judgements, such as degree of competition in the banking sector, degree of regulation of interest rates and savings, and the degree of private ownership of banks.

Fertility is a transformed variable, the average of the log of gross fertility over 10 years and collected from the Barro-Lee dataset.

Finally, terms of trade is from the Barro-Lee dataset and measures the change of export prices relative to import prices.

4.3 Political economy

Political economy includes three variables on government expenditure from different sources, and one on taxation.

Real government consumption net of defence and education was downloaded from the Barro-Lee dataset. It is a transformed variable of the average over ten years. It conveys the idea that defence serves to protect property from foreign occupiers thus increasing the expected return to investment, and that education increases the amount of human capital. They enhance growth. The rest of government expenditure would then reduce investment returns and decrease growth.

Alternative data on real government expenditure were available both from the Barro-Lee dataset and the Heston-Summers dataset. They measure roughly the same thing but are not similar in terms of values since the Heston-Summers data decomposition of GDP into consumption, investment and government sometimes sums above 100%. I cannot explain this phenomenon, so I would assume that the Barro-Lee dataset is more accurate and less biased.

The marginal tax rate contains a subjective measure of the burden of the highest marginal income tax rate. It is from the Fraser Institute.

4.4 Sociopolitical unrest

Sociopolitical unrest contains data on political instability, political rights and legal system and property rights.

Political instability is supposedly a variable that is labelled “rule-of law index” in Barro's (2000) paper and originates from the Barro-Lee dataset. I have constructed ten year averages and the original data is a constructed variable from the number of assassinations per million population per year and coups per year.

Political rights is also from the Barro-Lee dataset. It contains a subjective index between 1 and 7. This is probably the variable on “democracy index” in Barro's (2000) paper. There is a similar variable labelled “civil rights” from Barro-Lee, which is closely correlated to political rights, and could alternatively be used instead of political rights, but I have not done that.

The variable legal system and property rights was collected from the Fraser Institute. It is a subjective measure on the independence of courts, the impartiality of courts, i.e. military and political influence in legal processes. It also contains an index on protection of intellectual property.

4.5 National accounts

Lastly, since the neoclassical growth theory predicts conditional convergence, i.e. higher growth rates of poor countries and lower growth rates of rich countries, the starting level of GDP is required. A variable on the log of the starting level of real GDP per capita (constant price: chain series) was constructed from the Heston-Summers dataset.

Alternative data on investment expenditure can be found in the Heston-Summers and Barro-Lee datasets. Like in the case of government expenditure as explained above, I would assume that the Barro-Lee dataset is more accurate and this is the one to be used.

4.6 Geographic variables

Dummy variables were constructed separately for the continents of Africa and Latin America (all countries south of the United States and in the Caribbean). The list of countries last in Mankiw, Romer and Weil (1994) was used as for identification.

5. Regression results

In this section, some issues concerning the sample properties are discussed and then the regression results for the inequality models with and without fertility are discussed. An interpretation appears last.

This section presents the econometric results. The whole sample contains observations of 95 countries for three periods: 1965-75, 1975-85 and 1985-1995. They will be called period 1, period 2 and period 3, respectively. It is a panel dataset, i.e. a combination of a cross-country and time series sample.

At most, any regression can use data from 285 (95 countries times 3 time periods) observations. In reality, this number is always smaller for two reasons: first of all, data is not covered across the same time periods time for all variables, which I will refer to as *time omission of data*. For example, the Barro-Lee dataset has no data available after 1985 (1990 in some instances), and the Fraser Institute has no data collected prior to 1970. Second, there is data missing for certain countries at a single point of time, which I will refer to as a *country omission of data*. This is common in poor countries, where it is more difficult to collect data.

Omission of data causes problems, since it reduces the sample size and this in turn will reduce the degrees of freedom, abbreviated as *df*. A small sample size poses two of problems: first, estimated coefficients may fluctuate up an down owing to multicollinearity when an observation or a variable is added/removed, making the accuracy and reliability of estimates unpredictable; and second, coefficients may be rejected by mistake on basis of statistical tests, called a type II error.

However, there are ways to increase the sample size. One way is to look for alternative sources of data, such as using an alternative variable or using more observations of the same variable but collecting from a different source. If this is not feasible, data can be constructed forwards or backwards, called *proxying*. As mentioned above, the data collected from the Fraser Institute is not available prior to 1970. Use of a variable will result in the loss of degrees of freedom for the period 1965-1975, since it cannot be used with observations found in data of the other variables. However, there is a possibility of proxying the data prior to 1970, which was done for 1970-1980 to represent the earlier periods. This introduces a bias to the data, since the constructed data are not collected *per se*. However, as long as the gains from extending the data are greater than the problems caused by bias, it can be justified on grounds that the statistical estimates will be asymptotically efficient. This can at least solve the time omission of data, but the country omission of data is more difficult to overcome.

Other problems covered in econometric literature, e.g. heteroskedasticity, multicollinearity, omitted variable bias and normal distribution of the residuals will also be discussed. It should be pointed out that all regressions shown are heteroskedasticity-consistent estimator, which is asymptotically unbiased, that is it reduces the size of estimated variances and produces more statistically significant estimates than OLS does, which ensures that inference will not be misleading in the presence of heteroskedasticity.

5.1 Sample size and basic results

The first step of a robustness check is to reproduce the results of the regressions that are under investigation. Reproduction of the variables that are found in Barro's (2000) article was successful. However, some details differ when comparing regression 1 in my tables with Barro's table 1. First, I obtained the same signs on most of the coefficients in my regressions. Inflation has the wrong sign but is not statistically significant in my regression. In regressions 3 and 5, it is negative. One explanation is that my smaller sample size may make the effects of multicollinearity stronger, leading to fluctuating signs. Second, the coefficients on political instability is negative which is right in theory, because a higher number indicates more instability, leading to lower growth. It has the opposite sign to Barro, but he may have used a different variable than expected (please read section 4.4). Third, the size of Barro's coefficients is roughly one hundred times smaller than mine. This can be explained by linear scaling, probably of the dependent variable. This does not change the significance or sign of estimated coefficients. Fourth, Barro's t ratios tend to be larger than mine. He makes a regression of his full sample and on of his Gini sample. The latter contains only those observations that also have a Gini. Some countries do not have Ginis because of country omission of data. Regression 1 is equivalent to his full sample, I did not cmpute an equivalent of his Gini sample. Four possible explanations of the differing t ratios are the differences in sample size, the choice of robust estimator, the presence of time dummies in Barro's (2000) regressions to account for fixed effects of growth in the three time periods, or a different sample of the Ginis. Both of Barro's regressions have larger t ratios independent of the sample size. Probable explanations are that he chose for the dependent variable a set of Ginis that have a different quality to those of mine as mentioned in section 4.1.

The question is why my sample size is smaller. Barro in table one of his article has 240 and 146 df respectively for the full sample and the Gini sample. I have 156 and 117 respectively. When I first came across the sizeable WIID2 dataset of Ginis, the impression was that I would be able to collect a larger sample, but it has failed. Both my full sample in table one and the Gini sample in table two are smaller. There can be two explanations to this. First, I erased countries from my sample early on that did not have at least one observation on both Ginis (WIID2), education (Barro-Lee), GDP (Heston-Summers) and variables not used by Barro (Fraser Institute). The greatest loss probably occurred when removing countries that had no Ginis. The Barro-Lee dataset derives much of its content from the Heston-Summers dataset and therefore contain the same countries. This explains why both of my samples are smaller. Deletion by mistake offers another explanation, but is probably small.

Altogether, two conclusions can be drawn from this subsection: (1) my results are similar to those of Barro, but (2) I obtain smaller t ratios, and (3) the size of my sample was unexpectedly small.

5.2 Two models

As explained in 3.1, there are two models, one with fertility and another without. Because fertility seems to have a great deal of explanatory power, further regressions will appear in pairs, one with fertility and another without fertility.

5.3 Inequality results

Barro (2000, p. 16) has in his growth regressions first Gini and then Gini and the interaction variable. He regresses both with and without the fertility variable, altogether four different regressions. I will do the same for the sake of comparison.

Regression 2 shows the Gini variable and fertility. The coefficient on the Gini is expected to be negative as inequality would reduce investment and thus growth. I obtain a negative value that is not statistically significant, just like Barro. The other coefficients remain roughly unchanged in terms of the size. However, there is some reduction of the t ratios, but not sufficient in terms of statistical significance. This may be due to the Gini sample and that I did not use time dummies for the time periods to account for random changes over time in growth. A less likely explanation is the smaller sample size (117 versus 156).

In regression 2, the fertility variable can bias the Gini coefficient downwards because of multicollinearity[8]. An explanation for this is the positive correlation between fertility and the Ginis, i.e. a high birth rate is associated with a higher degree of inequality. In regression 3 the fertility variable is omitted to see whether there is a change in the sign of the Gini coefficient, which is now negative and significant. Thus, the degree of collinearity seems to be relevant.

---

8 Barro (2000, p. 17) does not mention the degree of pairwise correlation. I obtain one of 0.57 for 136 observations in my sample.

In regressions 4 and 5, an interaction variable between GDP and Gini (GDP multiplied with Gini) is added to regressions 2 and 3. The interaction variable, if it is positive, predicts that countries with a high level of GDP belong to one sample that requires inequality to produce growth and countries with a low level of GDP should for the same reason have less inequality. The coefficients on the Ginis have the right sign in both regressions but are not individually statistically significant. A test for the joint significance on the joint null hypothesis of both Gini variables being zero can also be carried out by means of the Wald test. Since this test has a greater power than the t test, a joint test can override the conclusion drawn from a t test, if the assumptions in the null are the same. The null can be rejected in regression 5 but not 4. This is in stark contrast to Barro's results, since he obtains similar results both with and without fertility. Probable explanations are again the Gini sample, the absence of time dummys and, less likely, a smaller sample size.

Barro performs a robustness check for his regressions where he divides up the sample in one with low GDP and another with high. With the results obtained, Barro (2000, p. 18) argues that "this piecewise-linear form tells a similar story to that found in the representation in the interaction between the Gini and log(GDP)". Thus, the results are the same here as in the case with the interaction variable.

Concerning the suitability of the models with and without fertility, it seems that fertility is a the better model. This is judged from the size of AIC and SIC in the tables, where a smaller value is preferable than a larger value. Regression 2 has a lower value than regressions 3, and regression 4 lower than regression 5. The same result is obtained with adjusted R^2, which can also be used but a higher value is then better.

I obtain the same results as Barro for the Gini regression, both with and without fertility, but not when including the interaction variable. Three conclusions can be drawn from this: (1) inequality alone can explain growth and (2) this result is independent of GDP per capita, i.e. no interaction between GDP per capita and inequality. (3) in an alternative model, fertility is accounted for and then income inequality is insignificant on all occasions.

5.4 Inclusion of additional control variables

In regressions 6 to 13, the additional control variables from the Fraser Institute are added and I use their lagged variables as IV. In regressions 6 to 9, I use the sample for all time periods and the average of the values between 1970 and 1980 are used as a proxy for time period 1 (see section 5.0), as there is no data available prior to 1970. In regressions 10 to 13, I use the data without the proxied values. This reduces the sample size but is important for comparison. Thus, regressions 6 and 10, 7 and 11, etc., are equivalent in terms of variables and should be compared.

The reason for the addition of these variables is to see whether it bears any change to the Gini variables. If they offer sufficiently more explanation to growth, the coefficients on the Ginis should turn insignificant.

The signs of the coefficients is correct for all, the only exception being marginal taxes which should have a positive sign. A higher value implies lower taxes, which in theory should enhance growth, but the sign of the coefficient contradicts this. It is significant at 10% in regression 13, but insignificant otherwise, thus it no reason to believe that it it significant on average.

As before, we first go on to check whether the Gini coefficient is significant. In regressions 6 and 10 that have fertility, the Gini variable is not statistically significant on basis of the t test. In regressions 7 and 11, the fertility variable is removed, and the Gini is highly significant. This confirms the results above that inequality alone can explain growth.

Next, the question is whether there is support for the interaction variable. This seems to be the case in those regressions that do not have fertility, that is the coefficients on the Ginis in 9 and 13 are jointly significant at 5% and 10% respectively. They are also individually significant at 5% in regression13, but this is less important as stated before. When adding fertility in 8 and 12, the Wald test statistic turns insignificant. The conclusion is that the relationship between inequality and growth disappears altogether after controlling for fertility.

The AIC and SIC draw the conclusion that the model with fertility is preferable. In every case when comparing regression 6 with 7, 8 with 9, etc, the test statistics of AIC and SIC are lower, those of adjusted R^2 higher.

This subsection does not contradict the results that Barro obtained. The Gini alone is significant with fertility but not without it. Including the interaction variable gives the same results to that of the Gini. It is very important that the results remain consistent across all regressions 6 to 13, not least since regressions 9 to 13 have only 57 observations and at most 17 variables.

I conclude that (1) there is strong support for the idea that inequality reduces growth; (2) there is a positive interaction between GDP and inequality; thus, more inequality is positive to growth in rich countries; (3) the model with fertility is better on every occasion.

5.5 Econometric issues

Problems of heteroskedasticity, multicollinearity and missing variables must be accounted for, since the interpretation might be wrong otherwise.

Heteroskedasticity is unlikely to occur because MacKinnon and White's robust variances should solve that problem. Unfortunately, I cannot use an empirical test for it owing to the software that I use, but the residuals are normally distributed at least at 5% in my regressions, except for regression 13.

Multicollinearity should not be a problem, because then at least some of the coefficients would be insignificant and fluctuate between negative and positive values as variables are added and removed. This has only happened for inflation, or it may just be an irrelevant variable and does not fit the model. The latter is probably more true, though I provide no proof by means of a test.

Missing variables cannot be a problem, since so many variables are included that cover the whole range of growth determinants. It can be argued that fertility is an important variable in the growth regressions on basis of the AIC and SIC tests and should not omitted from the growth model.

5.6 Interpretation

The broad conclusions are precisely that (1) inequality reduces growth generally, (2) more inequality enhances growth in rich countries and reduces it in poor countries, (3) these two effects are zero once we account for fertility.

(1) can be accepted without discussion. Regressions 3, 7 and 11 confirm this interpretation. As for (2), it should be noticed that the Wald test statistic in regression 5 contradicts this conclusion. But this could be a coincidence owing to the reasons mentioned before in section 5.3. The results from regressions 9 and 13 are stronger and thus the interaction variable is significant in my view. The conclusion in (3) is similar to (1): in all regressions that have fertility, the interpretations from (1) and (2) become invalid.

As for the results in (1) and (2), it is probable that inequality reduces growth in poor countries because of credit-market constraints. There, it is difficult to acquire the sums necessary to invest in human capital and fixed capital as the credit market is badly developed and not protected by social institutions. In rich countries, these constraints are less obvious and investment can take place which enhances growth (Barro, 2000, p. 18).

Unfortunately, none of the control variables seems to be able to explain the importance of credit-market constraints. Credit-market regulations appear strong in regressions 6 to 9, but not in 10 to 13. The opposite relationship is true for the variable sound money, i.e. it is insignificant in regressions 6 to

9, then more significant in 10 to 13. Their individual t ratios suggest that both do not possess sufficient significance to be taken seriously. Marginal income taxes seems to be a strong candidate on the other hand, but is rather related to the theory of the political economy. Thus higher marginal income taxes would enhance growth.

The distinction between (1) and (2) can be difficult, as they seem to contradict each other. Inequality seems to have different effects on growth depending on their level of development, but inequality also has an independent effect. One explanation is that the effect of inequality itself is absolute, whereas that of the interaction variable is relative. In other words, a rich country gains from less inequality compared to all countries, but amongst countries in its own group, more inequality would be positive to growth.

But then fertility removes these relationships of inequality entirely, and this is a significant effect and a better model as concluded earlier. This suggests that reducing gross fertility can enhance growth in the long run. One possible explanation is that high levels of fertility increases the need for present consumption and less is invested into human capital and fixed capital. If less remains invested, high fertility rates and low growth would endure.

6. Conclusion

This aim of this paper is to answer the question whether Barro's results paper in his 2000 paper would hold a robustness check. First, I tried to replicate his results by using the same sources and then add additional control variables to see if the results were reproducible.

The conclusions from his research are that (1) there is support for the idea that inequality would have an effect on growth, but only after controlling for fertility and not otherwise. (2) There is an interaction between GDP and inequality, meaning that more inequality would increase growth in rich countries and less inequality would increase growth in poor countries. Specifically, the latter holds even after controlling for fertility.

Like Barro, I find that conclusion (1) holds rather well, i.e. inequality is a growth determinant in the absence of fertility. Unlike Barro, I find (2) that the effect of the interaction between inequality and GDP on growth is conditional on the absence of fertility. (3) Combining (1) and (2), it suggests that fertility reduces both of those conclusions to zero, and this is the preferred model. After adding control variables from the Fraser Institute, there is no change in the conclusions overall.

The policy implication of this is that reducing fertility remains the strongest option to enhance growth rates. Reducing income inequality is less useful. There is probably a strong interaction between inequality, fertility and growth and reducing fertility coupled with investment might break this pattern.

Suggestions for future research are (1) to construct a larger sample than I have managed. First, for instance, the WIID2 dataset is larger than Deininger and Squire's, thus preferable. Second, use additional data from the World bank on GDP for the period 1995-2005, which would add yet another 10 year period. However, these GDP estimates are constructed differently from those in the Summer-Heston dataset, which requires a solution. (2) preferably to use Barro's sample which is obtainable upon order and then add other control variables. Combining (1) and (2) could give 200 observations.

Abbreviations

Abbreviation	***Explanation***
2SLS	Two-Stage Least Squares
AIC	Akaike Information Criterion
IV	Instrumental variables
OLS	Ordinary least squares
Robust 2SLS	2SLS with heteroskedasticity-corrected variances
SIC	Schwartz Information Criterion
WIID2	World Income Inequality Dataset ver. 2.0a

Regression results for GDP growth

Standard errors of estimated coefficients are in parentheses. All based on variances are MacKinnon and White (1985). Normal distribution of residuals is measured by the Chi-Square test of significance on the residuals. The joint distribution of Gini and GDP*Gini is tested by the Wald test. X refers to the same sign and a significant coefficient, or an insignificant coefficient as in Barro (2000), and √ otherwise, using a level of significance at 10%. X and √ appear for Gini, Gini*GDP and the Wald tests.

TABLE 1 – REGRESSIONS FOR GDP GROWTH

	(1)	(2)	(3)	(4)	(5)
No. of obs.	156	117	117	117	117
Constant	-14.4668 (-1.414)	-24.1027 (-1.587)	-27.6883 (-1.793)	-19.2831 (-1.046)	-20.1926 (-1.034)
Log of GDP per capita	7.68007 (2.809)	10.1025 (2.636)	9.14548 (2.254)	9.25668 (2.199)	7.87602 (1.759)
Log of GDP per capita squared	-0.639549 (-3.598)	-0.781537 (-3.283)	-0.672976 (2.645)	-0.753437 (-3.101)	-0.633691 (-2.437)
Gov consumption /GDP	-15.3420 (-4.177)	-14.6677 (-3.125)	-14.4254 (-2.920)	-14.3099 (-2.846)	-13.8486 (-2.664)
Political instability	-1.46854 (-0.573)	-2.12050 (-0.518)	-2.51907 (-0.558)	-2.17021 (-0.524)	-2.55682 (-0.560)
Political rights	0.481317 (0.801)	0.418011 (0.413)	0.538363 (0.557)	0.412401 (0.404)	0.521824 (0.527)
Political rights squared	-0.0694820 (-0.899)	-0.0506912 (-0.347)	-0.0730116 (-0.513)	-0.0498984 (-0.338)	-0.0709306 (-0.486)
Male Sec + High edu, 15 years	0.42331 (2.445)	0.430704 (1.594)	0.698653 (2.510)	0.440253 (1.593)	0.711666 (2.513)
Gross investment/GDP	9.27825 (2.757)	9.27850 (2.004)	12.8894 (3.381)	9.51882 (1.993)	13.1971 (3.425)
Log of gross fertility	-3.06985 (-3.634)	-2.94366 (-2.541)		-2.90925 (-2.457)	
Growth rate of terms of trade	5.47749 (1.143)	4.63126 (0.768)	2.18119 (0.345)	4.41941 (0.719)	1.92716 (0.294)
Inflation	7.16741 (0.628)	6.80244 (0.566)	-2.36623 (-0.242)	6.40296 (0.533)	-2.86014 (-0.290)
Gini		-0.0169375 X (-0.685)	-0.0463734 X (-1.949)	-0.0978459 √ (-0.460)	-0.172745 √ (-0.771)
Gini*GDP				0.0101101 √ (0.384)	0.0158628 √ (0.565)
Adj R^2	0.479387	0.457824	0.381663	0.446919	0.365804
F	13.9751	9.16273	7.50909	8.21032	6.57573
AIC	605.98	459.462	473.945	462.647	477.835
SIC	642.578	495.371	507.091	501.317	513.744
Two-sided crit. t-value at 5%, 10%	1.984, 1.660	1.984, 1.660	1.984, 1.660	1.984, 1.660	1.984, 1.660
N-dist of residuals	0.311288	0.102034	0.112545	0.101832	0.0863949
Probability of Gini and Gini*GDP = 0				0.750241 √	0.148957 √

TABLE 2 – REGRESSIONS FOR GDP GROWTH WITH FRASER INSTITUTE CONTROL VARIABLES

	(6)	*(7)*	*(8)*	*(9)*
No. of obs.	105	105	105	105
Constant	-39.5133 (-2.033)	-40.0967 (-2.226)	-23.8290 (-0.998)	-21.2648 (-0.960)
Log of GDP per capita	13.1929 (2.578)	11.6999 (2.566)	10.3762 (1.823)	8.47457 (1.687)
Log of GDP per capita squared	-0.957863 (-2.993)	-0.824128 (-2.932)	-0.861325 (-2.572)	-0.722086 (-2.483)
Gov consumption /GDP	-11.3699 (-2.098)	-12.2920 (-2.072)	-10.5533 (-1.924)	-11.2026 (-1.897)
Political instability	-2.82549 (-0.968)	-2.08169 (-0.622)	-2.76666 (-0.909)	-2.00503 (-0.584)
Political rights	1.01185 (1.135)	0.755288 (0.888)	0.964519 (1.024)	0.708825 (0.773)
Political rights squared	-0.113553 (-0.883)	-0.0761317 (-0.603)	-0.105795 (-0.775)	-0.0687897 (-0.505)
Male Sec + High edu, 15 years	0.320648 (1.595)	0.508269 (2.480)	0.344863 (1.729)	0.526464 (2.593)
Gross investment/GDP	5.31303 (0.881)	8.66931 (1.662)	5.98879 (0.984)	9.24282 (1.782)
Log of gross fertility	-2.75102 (-2.801)		-2.55975 (-2.525)	
Growth rate of terms of trade	13.3656 (2.134)	9.47174 (1.449)	12.9979 (1.909)	9.40317 (1.302)
Sound money	0.130153 (1.079)	0.0954830 (0.782)	0.111377 (0.933)	0.0776825 (0.646)
Credit market regulations	0.180274 (1.442)	0.190677 (1.701)	0.199956 (1.558)	0.213365 (1.861)
Legal system and property rights	0.129259 (0.362)	0.218583 (0.659)	0.165052 (0.479)	0.246780 (0.751)
Marginal taxes	-0.169498 (-1.415)	-0.166380 (-1.452)	-0.176620 (-1.446)	-0.177482 (-1.499)
Gini	-0.0304857 √ (-1.286)	-0.0547347 X (-2.877)	-0.288375 √ (-1.226)	-0.364025 √ (-1.477)
Gini*GDP			0.0321635 √ (1.130)	0.0388261 √ (1.286)
Adj R^2	0.509286	0.490174	0.49623	0.473845
F	8.19575	8.14224	7.40271	7.24402
AIC	392.707	396.063	396.277	400.016
SIC	435.171	435.873	441.394	442.48
2 -sided crit. T-value at 5%, 10%	1.987, 1662	1.987, 1.662	1.987, 1.662	1.987, 1.662
N-dist of residuals	0.815226	0.248978	0.687271	0.181431
Wald test: probability of Gini and Gini*GDP = 0			0.332135 √	0.0332088 X

TABLE 2 – REGRESSIONS FOR GDP GROWTH WITH FRASER INSTITUTE CONTROL VARIABLES

	(10)	*(11)*	*(12)*	*(13)*
No. of obs.	57	57	57	57
Constant	-28.4461 (-0.998)	-35.6043 (-1.158)	-8.02062 (-0.247)	-5.66345 (-0.164)
Log of GDP per capita	9.95039 (1.429)	9.70152 (1.271)	6.52180 (0.887)	4.96688 (0.634)
Log of GDP per capita squared	-0.735748 (-1.775)	-0.674393 (-1.478)	-0.642278 (-1.596)	-0.555434 (-1.285)
Gov consumption /GDP	-7.85748 (-1.221)	-6.17496 (-0.765)	-6.00141 (-1.004)	-3.94375 (-0.547)
Political instability	-1.66291 (-0.648)	-1.25108 (-0.406)	-1.26355 (-0.482)	-0.542848 (-0.181)
Political rights	0.865930 (0.543)	0.689396 (0.392)	0.473382 (0.321)	0.212589 (0.134)
Political rights squared	-0.0709234 (-0.299)	-0.0577412 (-0.218)	-0.00857649 (-0.039)	0.0198130 (0.085)
Male Sec + High edu, 15 years	0.192309 (0.781)	0.340053 (1.175)	0.189094 (0.823)	0.317507 (1.214)
Gross investment/GDP	6.24062 (1.051)	10.4637 (1.579)	7.89033 (1.605)	11.7814 (2.307)
Log of gross fertility	-3.09441 (-2.648)		-2.62436 (-2.342)	
Growth rate of terms of trade	10.0190 (1.129)	5.04865 (0.481)	10.8046 (1.162)	7.56494 (0.712)
Sound money	0.252664 (1.476)	0.269253 (1.390)	0.255603 (1.504)	0.260548 (1.381)
Credit market regulations	0.00292889 (0.018)	0.0594447 (0.347)	0.0335925 (0.174)	0.0910540 (0.435)
Legal system and property rights	0.182945 (0.647)	0.313928 (1.038)	0.247458 (0.951)	0.382806 (1.374)
Marginal taxes	-0.231660 (-1.645)	-0.252393 (-1.947)	-0.272605 (-1.915)	-0.305919 (-2.115)
Gini	-0.0354966 √ (-1.380)	-0.0599579 X (-2.219)	-0.451842 X (-1.850)	-0.626915 X (-2.197)
Gini*GDP			0.0515534 X (1.795)	0.0708348 X (2.100)
Adj R^2	0.635739	0.527858	0.626629	0.536866
F	7.51572	5.47203	6.87406	5.32768
AIC	188.818	202.987	191.209	203.189
SIC	221.507	233.633	225.941	235.878
2 -sided crit. T-value at 5%, 10%	2.020,1.683	2.018, 1.682	2.021, 1.684	2.020, 1.683
N-dist of residuals	0.73742	0.186551	0.164934	0.0204572
Wald test: probability of Gini and Gini*GDP = 0			0.17382 √	0.0548283 X

References

Alesina, Alberto and Rodrik, Dani, D*istributive Politics and Economic Growth*, The Quarterly Journal of Economics, May 1994, 465-490

Atkinson, A. B., and Bourguignon, F., *Introduction: Income Distribution and Economics*, *Handbook of Income Distribution: Volume 1*, Amsterdam: Elsevier, 2000

Barro, Robert J., *Economic Growth in a Cross Section of Countries*, The Quarterly Journal of Economics, Vl. 106, No.2 (May 1991), 407-433

____________, *Inequality and Growth in a Panel of Countries*, Journal of Economic Growth, March 2000, p. 5-32

Barro, Robert J., and Lee, Jong-Wha, *International Data on Educational Attainment: Updates and Implications*, Center for International Development at Harvard University, http://www2.cid.harvard.edu/cidwp/042.pdf, April 2000

Deaton, A., and Zaidi, S., *Guidelines for Constructing Consumption Aggregates for Welfare Analysis*, LSMS Working Paper No. 135, The World Bank, 2002

Litchfield, Julie A., *Income concerns us all*, The World Bank PovertyNet website, http://www.worldbank.org/poverty, 1999

Laffer, Arthur B., *The Laffer Curve: Past, Present and Future*, 1st of June, 2004, The Heritage Foundation, p. 1-18

Mankiw, Gregory N., Romer, David, and Weil, David N., *A Contribution to the Empirics of Economic Growth*, Quarterly Journal of Economics, May 1992, 406-437

Perotti, Robert, *Income Distribution, Politics and Growth*, The American Economic Review, 1992, p. 311-316

Romer, David, *Advanced Macroeconomics, Third Edition*, McGraw-Hill, 2005, 70-76, 144-54

Solow, Robert M., *A Contribution to the Theory of Economic Growth*, Quarterly Journal of Economics, LXX (1956), 65-94

____________, *Technical Change and the Aggregate Production Function*, The Review of economics and Statistics, 1957, 312-320

United Nations Diversity, World Institute for Development Economics Research (UNI-WIDER),

World Income Inequality Database v. 2.0a – User Guide and Data Resources, June 2005

Econometrics literature

Gujarati, Damodar N., *Basic Econometrics(Fourth Edition)*, McGraw Hill, 2003

Hinkley, D. V., Jackknifing in unbalanced situations, Technometrics 19, 1977, p. 285-292

Horn, S. D., Horn, R. A., and Duncan, D.B., Estimating heteroskedastic variances in linear models, Journal of the American Statistical Association 70, p. 380-385

Judge et al., *Introduction to theory and practice of econometrics – second edition*, Wiley, 1988

Kennedy, P., *Oh no! I got the wrong sign! What should I do?*, http://www.cba.ua.edu/~jlee/ec471/oh_no_I_got_the_wrong_sign.pdf, Simon Fraser University, 2002

MacKinnon, James G, and White, Halbert, *Some Heteroskedasticity-Consistent Covariance Matrix Estimators with improved finite sample properties*, Journal of Econometrics, 1985, p. 306-325