

Eckwert, Bernhard; Zilcha, Itzhak

**Working Paper**

## The Effect of Better Information on Income Inequality

CESifo Working Paper, No. 969

**Provided in Cooperation with:**

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

*Suggested Citation:* Eckwert, Bernhard; Zilcha, Itzhak (2003) : The Effect of Better Information on Income Inequality, CESifo Working Paper, No. 969, Center for Economic Studies and ifo Institute (CESifo), Munich

This Version is available at:

<https://hdl.handle.net/10419/76373>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# THE EFFECT OF BETTER INFORMATION ON INCOME INEQUALITY

BERNHARD ECKWERT  
ITZHAK ZILCHA

CESIFO WORKING PAPER No. 969  
CATEGORY 4: LABOUR MARKETS  
JUNE 2003

*An electronic version of the paper may be downloaded*  
• from the SSRN website: [www.SSRN.com](http://www.SSRN.com)  
• from the CESifo website: [www.CESifo.de](http://www.CESifo.de)

# THE EFFECT OF BETTER INFORMATION ON INCOME INEQUALITY

## Abstract

We consider an OLG economy with endogenous investment in human capital. Heterogeneity in individual human capital levels is generated by random innate ability. The production of human capital depends on each individual's investment in education. This investment decision is taken only after observing a signal which is correlated to his/her true ability, and which is used for updating beliefs. Thus, a better information system affects the distribution of human capital in each generation. Assuming separable and identical preferences for all individuals, we derive the following results in equilibrium: (a) If the relative measure of risk aversion is less (more) than 1 then more information raises (reduces) income inequality. (b) When a risk sharing market is available better information results in higher inequality regardless of the measure risk aversion.

JEL Code: D80, J24, J30.

Keywords: information system, income inequality, risk sharing markets.

Bernhard Eckwert  
Department of Economics  
University of Bielefeld  
33501 Bielefeld  
Germany  
[Eckwert@wiwi.uni-bielefeld.de](mailto:Eckwert@wiwi.uni-bielefeld.de)

Itzhak Zilcha  
The Eitan Berglas School of Economics  
Tel Aviv University  
Ramat Aviv  
69978 Tel-Aviv  
Israel  
[Izil@post.tau.ac.il](mailto:Izil@post.tau.ac.il)

We thank Alex Cukierman, Zvi Eckstein, Yona Rubinstein and Daniel Tsiddon for their valuable comments and suggestions.

## 1 Introduction

In recent years we have witnessed growing interest of economists in the determinants of income inequality and its evolution in dynamic models. Many papers in this field focus on the role of education systems for the distribution of income. These papers have produced mixed results, both on the theoretical and empirical level, suggesting that better public education systems do not necessarily lead to less income inequality [e.g., Glomm and Ravikumar (1992), Sylwester (2002a,2002b)]. Another main issue relates to the effects of various institutional settings and macroeconomic policies on the distribution of income in equilibrium [see, for example, Loury (1981), Galor and Zeira (1993), Benabou (1996), Orazem and Tesfatsion (1997), Aghion (2002)].

The endogenous growth literature has investigated the causes of inequality in income distribution, concentrating on four main transmission channels. Firstly, differences in unobservable individual talent may generate income inequality [e.g., Juhn et al. (1993)]. Secondly, based on subjective assessments of individual talent agents may choose different levels of investment in education [e.g., Galor and Tsiddon (1997), Viaene and Zilcha (2002)]. Thirdly, the stock of human capital of parents may affect their children's learning. If this linkage is specific to the household it will contribute to income inequality [e.g., Hassler and Mora (2000)]. Fourthly, the rate of technological change may affect the return to investment in education. Rubinstein and Tsiddon (2002) show that this mechanism accounts for a significant part of the inequality between different education groups. Our paper focuses on the first two channels. We develop an approach which embeds the social mechanism of selecting individual education levels in an endogenous growth model where agents differ with respect to ability. When young, each agent is screened by an information system which provides him with imperfect information about his talent. The central issue of our study is how better information (i.e., more efficient screening in the education period) affects the intragenerational income distribution.

Over the last decades the literature in the field of the economics of information has put much emphasis on the issue how welfare effects of information are related to the market structure of an economy. Many studies have examined the value of information in various partial equilibrium models [e.g., Blackwell (1951,1953), Green

(1981)] and in general equilibrium frameworks [e.g., Hirshleifer (1971,1975), Orosel (1996), Schlee (2001), Eckwert and Zilcha (2001a)]. However, to the best of our knowledge, this paper contains the first attempt to study the impact of information systems on the distribution of income in an endogenous growth model.

Our analytical framework is an OLG economy where investment in education is done under uncertainty. Individuals in the same generation differ in their (random) innate abilities. When ability is still unknown each individual decides how much ‘effort’ to invest in his/her education and training. The return to this investment, in term of wages during the working period, is random since it depends on the realization of the ability. The effort decision is made after observing a signal which contains information about the agent’s random ability. We analyze the effect of better information system, i.e., more efficient screening, upon the distribution of income in each generation. Of course, better information has a significant impact on the accumulation of human capital as well and, hence, on economic growth. This aspect has been studied in a separate paper [see, Eckwert and Zilcha (2001b)] to which we will refer occasionally.

Our analysis concentrates on the intragenerational distribution of average income across groups of individuals with a given, but unknown, ability. We demonstrate that income inequality may either increase or decrease with a better information system. More precisely, assuming constant relative risk aversion utility functions, we show that better information increases (decreases) income inequality if the relative measure of risk aversion is smaller (larger) than 1. Risk aversion plays such a crucial role because it affects the behavior of the optimal effort level: the effort level increases (decreases) as the agent receives a more favorable information signal if relative risk aversion is below 1 (above 1). Thus, better information may either increase or decrease the dispersion in the distribution of investments in education – a fact which critically contributes to our result about the consequences of better information for income inequality.

We also study the role of risk sharing arrangements for the link between information and the distribution of income. Assuming that the signals convey information related to an insurable part of the random ability (or, the rate of return to investment in human capital) we show that better information always enhances income

inequality. By contrast, if the information system is fixed, risk sharing reduces income inequality if relative risk aversion exceeds 1.

The paper is organized as follows. In section 2 we describe the OLG economy and define our concept of informativeness. In section 3 we study the effect of better information on income inequality. Section 4 deals with the same issue in the presence of an insurance market. In section 5 we analyze the consequences of risk sharing on income inequality for a given information system. To facilitate reading all proofs are relegated to section 6, the Appendix.

## 2 The Model

Consider an overlapping generations economy with a single commodity which is traded each period  $t = 0, 1, \dots$ . The commodity can either be consumed or used as an input (physical capital) in a production process (see, e.g., Azariadis and Drazen (1990)). The generations reproduce identically over time. Each generation consists of a continuum of individuals who live for three periods. In their first period ('youth') agents obtain education while they are still supported by their parents. In their second period ('middle-age') they work and spend part of the labor income for consumption; and in their third period ('retirement') they consume their savings. We denote by  $G_t, t = 0, 1, \dots$  the generation of all agents born at date  $t - 1$ .

The agents within a given generation differ with regard to their human capital. Human capital,  $\tilde{h}^i$ , of agent  $i \in G_t$  is determined by a random innate ability,  $\tilde{A}^i$ , the effort  $e^i \in \mathbb{R}_+$  invested in education by this individual, and the 'environment' when education takes place represented by the average human capital of agents in the previous generation:

$$\tilde{h}^i = \tilde{A}^i g(H_{t-1}, e^i) \quad (1)$$

$H_{t-1}$  denotes the average human capital of  $G_{t-1}$  (to be defined below), and  $g : \mathbb{R}_+^2 \rightarrow \mathbb{R}_+$  is a twice differentiable function which is strictly increasing in both arguments.

When 'young' the ability of agent  $i$  is uncertain. The random variable  $\tilde{A}^i$  realizes at the beginning of agent  $i$ 's middle-age period and takes values in some interval  $\mathcal{A} \subset \mathbb{R}_+$ . We assume that the random variables  $\tilde{A}^i, i \in G_t, t = 0, 1, \dots$ , are i.i.d.,

so that the ex ante distribution of ability is the same for all agents.<sup>1</sup>

Before an agent chooses optimal effort in the youth period he receives a signal which contains information about his unknown ability. We consider information systems in which signals are represented by a random variable  $\tilde{y}$  taking values in  $Y \subset \mathbb{R}$ . Each agent  $i \in G_t$ ,  $t = 0, 1, \dots$ , with ability  $A$  observes an individual signal  $y^i$  which is drawn randomly from the distribution of the random variable  $(\tilde{y}|A)$ .<sup>2</sup> By construction, this individual signal is correlated to  $i$ 's ability. Therefore, when agent  $i$  makes his decision about how much effort  $e^i$  to invest in education, the relevant c.d.f. for random ability is the posterior distribution of  $\tilde{A}^i$  given the individual signal  $y^i$ . Since the random variables  $\tilde{A}^i \in G_t$ ,  $t = 0, 1, \dots$ , are i.i.d, any two agents who receive the same signal will base their respective effort decisions on the same posterior distribution of ability.

For convenience we normalize the measure of agents in each generation to 1:

$$\int_{\mathcal{A}} \nu(A) dA = 1,$$

where  $\nu(A)$  is the (Lebesgue)-density of agents with ability  $A$ . Denote by  $f(\cdot|A)$  the density of the random variable  $(\tilde{y}|A)$ , and by  $\nu_y(\cdot)$  the density of the random variable  $(\tilde{A}|y)$ . Using this notation, the distribution of signals received by agents in the same generation has the density<sup>3</sup>

$$\mu(y) = \int_{\mathcal{A}} f(y|A) \nu(A) dA. \quad (2)$$

And average ability of all agents who have received the signal  $y$  is

$$\bar{A}(\nu_y) := \int_{\mathcal{A}} A \nu_y(A) dA. \quad (3)$$

The agents are expected utility maximizers with von-Neumann Morgenstern lifetime utility function

$$U(e, c_1, c_2) = v(e) + u_1(c_1) + u_2(c_2). \quad (4)$$

---

<sup>1</sup>In the sequel we will therefore suppress the index  $i$  and write  $\tilde{A}$  instead of  $\tilde{A}^i$ . Note, however, that in general the random variables  $\tilde{A}^i$  and  $\tilde{A}^j$  differ for  $i \neq j$ ; only their distributions are the same.

<sup>2</sup>Throughout the paper we shall refer to the realizations of  $\tilde{y}$  as signals, and to the realizations of the  $\tilde{y}^i$ 's as *individual* signals.

<sup>3</sup>Note that, by the law of large numbers,  $\mu$  does not depend on  $t$ .

Individuals derive negative utility from ‘effort’ while they are young and positive utility from consumption in the working period,  $c_1$ , and from consumption in the retirement period,  $c_2$ .

**Assumption 1** *The utility functions  $v$  and  $u_j$ ,  $j = 1, 2$ , have the following properties:*

- (i)  $v : \mathbb{R}_+ \rightarrow \mathbb{R}_-$  is decreasing and strictly concave,
- (ii)  $u_j : \mathbb{R}_+ \rightarrow \mathbb{R}$  is increasing and strictly concave,  $j = 1, 2$ .

In each period, competitive firms transform physical capital  $K$  and human capital  $H$  into a consumption/investment good. The transformation process can be described by an aggregate production function  $F(K, H)$  which exhibits constant returns to scale. If individual  $i$  supplies  $l^i$  units of labor in his ‘working period’, his supply of human capital equals  $l^i h^i$ . We assume inelastic labor supply, i.e., that  $l^i$  is a constant and it is equal to 1 for all  $i$ .

**Assumption 2**  *$F(K, H)$  is concave, homogeneous of degree 1, and satisfies  $F_K > 0$ ,  $F_H > 0$ ,  $F_{KK} < 0$ ,  $F_{HH} < 0$ .*

We also assume throughout this paper full international capital mobility, while human capital is assumed to be immobile. As a consequence, at each date  $t$  the interest rate  $\bar{r}_t$  is exogenously given and marginal productivity of aggregate physical capital  $K_t$  is equal to  $1 + \bar{r}_t$  (assuming full depreciation of capital in each period). Thus, given the aggregate stock of human capital at date  $t$ ,  $H_t$ , the stock  $K_t$  must adjust such that

$$1 + \bar{r}_t = F_K(K_t, H_t) \quad t = 1, 2, 3, \dots \quad (5)$$

holds. Equation (5) and Assumption 3 imply that  $\frac{K_t}{H_t}$  is determined by the international rate of interest  $\bar{r}_t$ . Hence the wage rate  $w_t$  (price of one unit of human capital), is given in equilibrium by the marginal product of aggregate human capital, is also determined once  $\bar{r}_t$  is given. Thus we may write

$$w_t = F_L\left(\frac{K_t}{H_t}, 1\right) =: \zeta(\bar{r}_t) \quad t = 1, 2, 3, \dots \quad (6)$$

Now let us consider the optimization problem that each  $i \in G_t$  faces, given  $\bar{r}_t, w_t$ , and  $H_{t-1}$ . At date  $t - 1$ , when ‘young’, this individual chooses the optimal level of effort employed in obtaining education. This decision is made under random ability  $\tilde{A}$ , but after the individual signal  $y^i$  has been observed. The decision about saving,  $s^i$ , to be used for consumption when ‘old’ is taken in the second period, after the realization of  $\tilde{A}$ , and hence when the human capital  $h^i$  is known. Thus  $s^i$  will depend on  $h^i$  via the wage earnings  $w_t h^i$ .

For given levels of  $h^i, w_t$  and  $\bar{r}_t$ , the optimal saving decision of individual  $i \in G_t$  is determined by

$$\begin{aligned} & \max_{s^i} u_1(c_1^i) + u_2(c_2^i) \\ & \text{s.t. } c_1^i = w_t h^i - s^i \\ & \quad c_2^i = (1 + \bar{r}_t)s^i \end{aligned} \tag{7}$$

and satisfies the necessary and sufficient first order condition

$$-u'_1(w_t h^i - s^i) + (1 + \bar{r}_t)u'_2((1 + \bar{r}_t)s^i) = 0 \tag{8}$$

for all  $h^i$ . From equation (8) we find optimal saving as a function of each realized  $h^i$ , i.e.,  $s^i = s_t(h^i)$ . The optimal level of effort invested in education,  $e^i$ , is determined by

$$\begin{aligned} & \max_{e^i} E[v(e^i) + u_1(\tilde{c}_1^i) + u_2(\tilde{c}_2^i) | y^i] \\ & \text{s.t. } \tilde{c}_1^i = w_t \tilde{h}^i - \tilde{s}^i \\ & \quad \tilde{c}_2^i = (1 + \bar{r}_t)\tilde{s}^i, \end{aligned} \tag{9}$$

where  $\tilde{h}^i$  is given by equation (1) and  $\tilde{s}^i$  satisfies equation (8). Due to the Envelope theorem and the strict concavity of the utility functions, problem (9) has a unique solution determined by the first order condition

$$v'(e^i) + w_t g_2(H_{t-1}, e^i)E[\tilde{A}u'_1(w_t \tilde{h}^i - \tilde{s}^i) | y^i] = 0. \tag{10}$$

Since  $u'_1$  is a decreasing function we also conclude from (8) that  $s_t(h^i)$  and  $w_t h^i - s_t(h^i)$  are both increasing in  $h^i$ . This implies, in particular, that the LHS in (10) is strictly decreasing in  $e^i$ . Similarly, from equation (10) we obtain the optimal level

of effort as a function of the conditional distribution  $\nu_{yi}$ , i.e.,  $e^i = e_t(\nu_{yi})$ . Note that any two agents in generation  $t$  who receive the same individual signal will choose the same effort level.

Using (2) and (3) the aggregate stock of human capital at date  $t$  can be expressed as

$$H_t = E_y[\bar{h}_t(\nu_y)] = \int_Y \bar{h}_t(\nu_y) \mu(y) dy, \quad (11)$$

where

$$\bar{h}_t(\nu_y) := \bar{A}(\nu_y) g(H_{t-1}, e_t(\nu_y)) \quad (12)$$

is the average human capital of agents in  $G_t$  who have received the signal  $y$ .

**Definition 1** Given the international interest rates  $(\bar{r}_t)$  and the initial stock of human capital  $H_0$ , a competitive equilibrium consists of a sequence  $\{(e^i, s^i)_{i \in G_t}\}_{t=1}^\infty$ , and a sequence of wages  $(w_t)_{t=1}^\infty$ , such that:

- (i) At each date  $t$ , given  $\bar{r}_t$ ,  $H_{t-1}$ , and  $w_t$ , the optimum for each  $i \in G_t$  in problems (9) and (7) is given by  $(e^i, s^i)$ .
- (ii) The aggregate stocks of human capital,  $H_t, t = 1, 2, \dots$ , satisfy (11).
- (iii) Wage rates  $w_t, t = 1, 2, \dots$ , are determined by (6).

## 2.1 Information Systems

The ability of each individual  $i$  is a random variable  $\tilde{A}^i$ . We assume that the random variables  $\tilde{A}^i$  are i.i.d. across individuals in  $G_t$ ,  $t = 0, 1, 2, \dots$ , and that they all have the same distribution as  $\tilde{A}$ . We shall refer to the realizations of  $\tilde{A}$  as the states of nature. Before a young agent with ability  $A$  chooses an optimal effort level he observes an individual signal which is drawn randomly from the distribution of the random variable  $(\tilde{y}|\tilde{A}^i = A) = (\tilde{y}|\tilde{A} = A) =: (\tilde{y}|A)$ . Thus, ex ante the conditional distributions of the individual signals are identical. For convenience, we shall refer to the realizations of  $\tilde{y}$  simply as signals.

An information system, which will be represented by  $f : Y \times \mathcal{A} \rightarrow \mathbb{R}_+$  throughout the paper, specifies for each state of nature  $A$  a conditional probability function over

the set of signals. The positive real number  $f(y|A)$  defines the conditional probability (density) that if the state of nature is  $A$ , then the signal  $y$  will be sent. We assume throughout the paper, unless stated otherwise, that the densities  $\{f(\cdot|A), A \in \mathcal{A}\}$  have the strict monotone likelihood ratio property (MLRP):  $y' > y$  implies that for any given (nondegenerate) prior distribution for  $A$ , the posterior distribution conditional on  $y'$  dominates the posterior distribution conditional on  $y$  in the first-order stochastic dominance. This implies that higher signal is ‘good news’ (see Milgrom (1981)). As a consequence,  $\int_{\mathcal{A}} \varphi(A) \nu_{y'}(A) dA > \int_{\mathcal{A}} \varphi(A) \nu_y(A) dA$  holds for any strictly increasing function  $\varphi$ .

By the law of large numbers, the prior distribution over  $\mathcal{A}$  coincides with the ex post distribution of ability across agents. Also the prior distribution over  $Y$  coincides with the ex post distribution of individual signals across agents and, hence, is given by equation (2). Finally, the density function for the updated posterior distribution over  $\mathcal{A}$  is

$$\nu_y(A) = f(y|A)\nu(A)/\mu(y). \quad (13)$$

Blackwell (1953) proposed a criterion that compares different information systems by their informational contents. Suppose  $\bar{f}$  and  $\hat{f}$  are two information systems with associated density functions  $\bar{\nu}_y$ ,  $\hat{\nu}_y$ ,  $\bar{\mu}$ ,  $\hat{\mu}$ . Blackwell defined the informativeness of an information system as follows:

**Definition 2** Let  $\bar{f}$  and  $\hat{f}$  be two information systems.  $\bar{f}$  is said to be more informative in the Blackwell sense than  $\hat{f}$  (expressed by  $\bar{f} \succ_{\text{inf}}^B \hat{f}$ ), if there exists an integrable function  $\lambda : Y^2 \rightarrow \mathbb{R}_+$  such that

$$\int_Y \lambda(y', y) dy' = 1 \quad (14)$$

holds for all  $y$ , and

$$\hat{f}(y'|A) = \int_Y \bar{f}(y|A) \lambda(y', y) dy \quad (15)$$

holds for all  $A \in \mathcal{A}$ .

According to this criterion,  $\bar{f} \succ_{\text{inf}}^B \hat{f}$  holds if  $\hat{f}$  can be obtained from  $\bar{f}$  through a process of randomization, i.e., by adding some random noise.

Given an information system  $f$  and an ability level  $A$ , define

$$L_f^A(z) := \text{pr} \left[ \frac{f_A}{f}(\tilde{y}|A) \leq z \right] = \int_{\frac{f_A}{f}(y|A) \leq z} f(y|A) dy$$

where  $f_A$  denotes the partial derivative.  $L_f^A(z)$  is called the *likelihood ratio distribution* of an agent with ability  $A$  under information system  $f$ .

**Lemma 1**  $\frac{f_A}{f}(y|A)$  is monotone increasing in  $y$  and, hence, the likelihood ratio distribution function can be written as

$$L_f^A(z) = F \left( \left( \frac{f_A}{f} \right)^{-1}(z) \middle| A \right), \quad (16)$$

where  $F(y|A)$  is the c.d.f. for the random variable  $(\tilde{y}|A)$ .

Kim (1995) has shown that the likelihood ratio distribution under  $\bar{f}$ ,  $L_{\bar{f}}^A(z)$ , is a mean preserving spread of that under  $\hat{f}$ ,  $L_{\hat{f}}^A(z)$ , if  $\bar{f}$  is more informative (in the Blackwell sense) than  $\hat{f}$ :

**Lemma 2** Let  $\bar{f}$  and  $\hat{f}$  be two information systems such that  $\bar{f} \succ_{\text{inf}}^B \hat{f}$ . For any  $A \in \mathcal{A}$ ,  $L_{\bar{f}}^A(z)$  is a mean preserving spread (MPS) of  $L_{\hat{f}}^A(z)$ . That is, both distribution functions have the same mean and

$$\int^{z'} \bar{F} \left( \left( \frac{\bar{f}_A}{\bar{f}} \right)^{-1}(z) \middle| A \right) dz \geq \int^{z'} \hat{F} \left( \left( \frac{\hat{f}_A}{\hat{f}} \right)^{-1}(z) \middle| A \right) dz \quad \forall z' \in \mathbb{R} \quad (17)$$

with the strict inequality holding for some range of  $z' \in \mathbb{R}$  with positive measure.

Proof: see Kim (1995).

Inequality (17) can be transformed into an integral condition that will turn out to be a useful tool for the analysis in this paper.

**Lemma 3** Inequality (17) is satisfied for all  $z' \in \mathbb{R}$  if and only if the following integral condition holds for all  $\vartheta \in [0, 1]$ :

$$S(\vartheta|A) := \int_0^\vartheta \left[ \frac{\bar{f}_A}{\bar{f}} \left( \bar{F}^{-1}(s|A) \middle| A \right) - \frac{\hat{f}_A}{\hat{f}} \left( \hat{F}^{-1}(s|A) \middle| A \right) \right] ds \leq 0. \quad (18)$$

Proof: This lemma is a straightforward modification of Proposition 3 in Demougin and Fluet (2001). The proof is therefore omitted.  $\square$

Our analysis focuses on the following concept of informativeness:

**Definition 3 (informativeness)** Let  $\bar{f}$  and  $\hat{f}$  be two information systems.  $\bar{f}$  is more informative than  $\hat{f}$  (expressed by  $\bar{f} \succ_{\text{inf}} \hat{f}$ ), if:

- (i) [Adding Noise Reduces Informativeness] for any  $A \in \mathcal{A}$ , the likelihood ratio distribution under  $\bar{f}$ ,  $L_{\bar{f}}^A(z)$ , is a MPS of that under  $\hat{f}$ ,  $L_{\hat{f}}^A(z)$ ,
- (ii) [Good News Become Better News Under More Reliability] for any  $A \in \mathcal{A}$  and any distribution of  $\tilde{A}$ ,

$$\frac{E^{\bar{f}}[\tilde{A}|\bar{F}^{-1}(s''|A)]}{E^{\bar{f}}[\tilde{A}|\bar{F}^{-1}(s'|A)]} \geq \frac{E^{\hat{f}}[\tilde{A}|\hat{F}^{-1}(s''|A)]}{E^{\hat{f}}[\tilde{A}|\hat{F}^{-1}(s'|A)]} \quad (19)$$

holds for any two signals  $s'' \geq s'$ .

According to Lemma 2, condition (i) is weaker than the Blackwell criterion, i.e., condition (i) is implied by  $\bar{f} \succ_{\text{inf}}^B \hat{f}$ . Condition (ii) postulates that under a better information system the conditional expectation of ability reacts more sensitively to changes in the (transformed) signal  $s$ . In this sense an increase in the transformed signal  $s$  constitutes better news if the information system is more informative, i.e., if the signal is more reliable. Note that

$$\frac{E^{\bar{f}}[\tilde{A}|\bar{F}^{-1}(s|A)]}{E^{\hat{f}}[\tilde{A}|\hat{F}^{-1}(s|A)]} \quad (20)$$

is monotone increasing in the signal  $s$  for  $\bar{f} \succ_{\text{inf}} \hat{f}$ , if and only if condition (ii) holds.

Observe that any two information systems which can be ordered according to Blackwell's criterion,  $\bar{f} \succ_{\text{inf}}^B \hat{f}$ , satisfy the inequality in (19) for  $s' = 0$  and  $s'' = 1$ . In particular, the term in (20) is less than 1 for  $s = 0$  and larger than 1 for  $s = 1$ .

This observation follows from the following assessment (for arbitrary  $\hat{A} \in \mathcal{A}$ ):<sup>4</sup>

$$\begin{aligned}
E^{\bar{f}}[\tilde{A}|\bar{F}^{-1}(0|\hat{A})] &= E^{\bar{f}}[\tilde{A}|\underline{y}] = \int_{\mathcal{A}} A \bar{\nu}_{\underline{y}}(A) dA \\
&< \frac{1}{\hat{\mu}(\underline{y})} \int_Y \bar{\mu}(y') \lambda(\underline{y}, y') \int_{\mathcal{A}} A \bar{\nu}_{y'}(A) dA dy' \\
&= \int_{\mathcal{A}} A \hat{\nu}_{\underline{y}}(A) dA = E^{\hat{f}}[\tilde{A}|\underline{y}] = E^{\hat{f}}[\tilde{A}|\hat{F}^{-1}(0|\hat{A})]. \quad (21)
\end{aligned}$$

By a similar argument we get

$$E^{\bar{f}}[\tilde{A}|\bar{F}^{-1}(1|\hat{A})] > E^{\hat{f}}[\tilde{A}|\hat{F}^{-1}(1|\hat{A})], \quad \forall \hat{A} \in \mathcal{A}. \quad (22)$$

From (21) and (22) it is immediate that the conditional expectations  $E^{\bar{f}}[\tilde{A}|\bar{F}^{-1}(s|\hat{A})]$  and  $E^{\hat{f}}[\tilde{A}|\hat{F}^{-1}(s|\hat{A})]$  cross at least once.

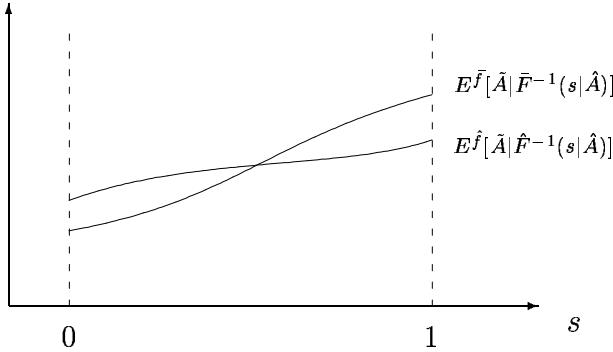


Figure 1: Conditional expectations under information systems  $f$  and  $\hat{f}$ .

Thus the Blackwell criterion has important implications for the curvatures of conditional expectations under the information systems  $\bar{f}$  and  $\hat{f}$ . These implications

---

<sup>4</sup>The second equality makes use of Bayes' rule which implies

$$\hat{\nu}_y(A) = \frac{1}{\hat{\mu}(y)} \int_Y \bar{\mu}(y') \bar{\nu}_{y'}(A) \lambda(y, y') dy'.$$

are strengthened by the condition in (19), which implies that the conditional expectations in Figure 1 have a *unique* intersection point.<sup>5</sup>

### Remark

Consider the following deterministic transformation of the signal variable:  $s \rightarrow \hat{s} := \zeta(s)$ ,  $\zeta$  strictly monotone. Obviously, this transformation does not affect the informativeness of the information system  $f = \bar{f}, \hat{f}$  because  $\zeta(s)$  can be inferred from  $s$  and vice versa. If  $\zeta(\cdot)$  is strictly increasing, the MLRP of  $f = \bar{f}, \hat{f}$  is preserved under the transformation. For strictly decreasing  $\zeta(\cdot)$  the transformation reverses the MLRP of  $f = \bar{f}, \hat{f}$  because  $\hat{s}'' < \hat{s}'$  holds iff  $s'' > s'$ . This implies that (19) holds with reversed inequality sign with respect to the new signal  $\hat{s}$ . Thus, when comparing the informativeness of two information systems which satisfy MLRP in reverse, the inequality sign in (ii) of Definition 3 needs to be reversed.

## 3 Information and Inequality Without Risk Sharing

To facilitate the comparison of income distributions under different information systems we restrict the utility functions  $u_1(\cdot)$ ,  $u_2(\cdot)$ , and  $v(\cdot)$  to be in the family of CRRA:

$$u_1(c_1) = \frac{c_1^{1-\gamma_u}}{1-\gamma_u}; \quad u_2(c_2) = \beta \frac{c_2^{1-\gamma_u}}{1-\gamma_u}; \quad v(e) = -\frac{e^{\gamma_v+1}}{\gamma_v+1}. \quad (23)$$

$\gamma_u$  and  $\gamma_v$  are strictly positive constants.  $\gamma_v$  parametrizes the curvature of the utility function in the youth period,  $v$ ; and  $\gamma_u$  parametrizes the curvature of the utility functions in the middle age period and retirement period,  $u_i$ ,  $i = 1, 2$ .

---

<sup>5</sup>In many economic applications signals are generated according to  $s = A + \delta \tilde{s}$ . This specification implies that, as an approximation (which is exact if  $\tilde{A}$  and  $\tilde{s}$  are jointly normal or if the log of their densities is quadratic), conditional expectations can be represented as  $E[\tilde{A}|s] = E\tilde{A} + \vartheta(s - Es)$  with  $\vartheta = \sigma_A^2 / (\sigma_A^2 + \delta^2 \sigma_\epsilon^2)$ . Typically, in these applications  $\vartheta$  is used as a measure of informativeness. In such a framework condition (19) is always satisfied: Let  $\bar{f}$  and  $\hat{f}$  be information systems corresponding to  $\bar{\vartheta}$  and  $\hat{\vartheta}$ ,  $\bar{\vartheta} > \hat{\vartheta}$ . We conclude

$$\frac{E\bar{f}[\tilde{A}|s]}{E\hat{f}[\tilde{A}|s]} = \frac{E\tilde{A} + \bar{\vartheta}(s - Es)}{E\tilde{A} + \hat{\vartheta}(s - Es)},$$

which is increasing in  $s$ .

We also assume that the function  $g$  in (1) has the form

$$g(H, e) = \hat{g}(H)e^\alpha, \quad (24)$$

where  $\hat{g}$  is strictly increasing in  $H$ , and  $\alpha \in (0, 1)$ .

Using the functional forms of  $u_j$ ,  $j = 1, 2$ , in (23), it follows from equation (8) that, given  $\bar{r}_t$  and  $w_t$ , the saving  $s^i$  is proportional to the human capital level  $h^i$ . In other words, for each  $t$  and for each  $i \in G_t$  we have:

$$s^i = m_t h^i, \quad 0 < m_t < w_t, \quad t = 1, 2, \dots \quad (25)$$

The specifications in (23), (24) and (25) allow us to solve equation (10) for the optimal effort level as a function of the conditional distribution  $\nu_y$ :<sup>6</sup>

$$e_t(\nu_y) = \delta_t \left( E[\tilde{A}^{1-\gamma_u} | y] \right)^{\rho/\alpha} \quad (26)$$

where

$$\delta_t := \left[ \frac{\alpha w_t (\hat{g}(H_{t-1}))^{1-\gamma_u}}{(w_t - m_t)^{\gamma_u}} \right]^{\rho/\alpha}; \quad \rho = \frac{\alpha}{\gamma_v + \alpha(\gamma_u - 1) + 1}.$$

We will discuss the role of information for the distribution of expected individual incomes across agents of different types *before* ability and signals are revealed. For that purpose we focus on the average income of all agents with given ability  $A$ . The distribution of average income within this class of agents across different ability levels will serve as a measure of inequality.

Let

$$\begin{aligned} I_t^f(A) &:= \int_Y w_t \tilde{h} f(y|A) dy \\ &= w_t \hat{g}(H_{t-1}) \delta_t^\alpha A \int_Y \left( E^f[\tilde{A}^{1-\gamma_u} | y] \right)^\rho f(y|A) dy \end{aligned} \quad (27)$$

be the expected income, as of date  $t - 1$  of an agent in generation  $t$  with ability  $A$ . We measure ex ante income inequality by the elasticity of expected income with respect to ability.

---

<sup>6</sup>Since all agents in generation  $t$  who receive the same signal will make the same savings and effort decisions we suppress the index  $i$  in the sequel.

**Definition 4 (income inequality)** *Income distribution under information system  $\bar{f}$  is said to be more unequal than income distribution under information system  $\hat{f}$ , if*

$$\varepsilon[I_t^{\bar{f}}, A] := \frac{\partial I_t^{\bar{f}}(A)}{\partial A} \frac{A}{I_t^{\bar{f}}(A)} \geq \frac{\partial I_t^{\hat{f}}(A)}{\partial A} \frac{A}{I_t^{\hat{f}}(A)} =: \varepsilon[I_t^{\hat{f}}, A] \quad (28)$$

holds for all  $t \geq 0$  and  $A \in \mathcal{A}$ .

We will show below (cf. part (i) in Theorem 1) that for  $\gamma_u \leq 1$  and given  $A \in \mathcal{A}$  the elasticity  $\varepsilon[I_t^f, A]$  is bounded from below by  $\varepsilon[I_t^{f^0}, A]$ , where  $f^0$  denotes the uninformative system. From (27) it is immediate that  $\varepsilon[I_t^{f^0}, A] = 1$  for all  $A$ . Similarly, for  $\gamma_u \geq 1$  the elasticity  $\varepsilon[I_t^f, A]$  is bounded from below by  $\varepsilon[I_t^{f^1}, A]$  where  $f^1$  is the fully informative system. Since under  $f^1$  the signal reveals an agent's talent, (27) reduces to

$$[w_t \hat{g}(H_{t-1}) \delta_t^\alpha]^{-1} I_t^{f^1}(A) = A^{1+(1-\gamma_u)\rho}$$

and, hence,  $\varepsilon[I_t^{f^1}, A] = 1 + (1 - \gamma_u)\rho = (1 + \gamma_v)/[1 + \gamma_v + \alpha(\gamma_u - 1)] > 0$ . Thus the elasticities in (28) are strictly positive.

Remark: The above definition of income inequality implies the definition given by Atkinson (1970) in the sense that the normalized income under  $\hat{f}$ ,  $\|I_t^{\hat{f}}(A)\| := I_t^{\hat{f}}(A)/E[I_t^{\hat{f}}(A)]$ , dominates in second degree stochastic dominance the normalized income under  $\bar{f}$ ,  $\|I_t^{\bar{f}}(A)\| := I_t^{\bar{f}}(A)/E[I_t^{\bar{f}}(A)]$ . In other words,  $\|I_t^{\bar{f}}(A)\|$  and  $\|I_t^{\hat{f}}(A)\|$  differ by a MPS and, hence, the Lorenz curve for  $\|I_t^{\hat{f}}(A)\|$  lies strictly above that for  $\|I_t^{\bar{f}}(A)\|$ .

Observe that

$$\text{sign}(\varepsilon[I_t^{\bar{f}}, A] - \varepsilon[I_t^{\hat{f}}, A]) = \text{sign}(\varepsilon[\bar{I}^{\bar{f}}, A] - \varepsilon[\bar{I}^{\hat{f}}, A]), \quad (29)$$

where

$$\bar{I}^f(A) := I_t^f(A)/w_t \hat{g}(H_{t-1}) \delta_t^\alpha A, \quad f = \bar{f}, \hat{f}.$$

$\bar{I}^f(A)$  can be rewritten as

$$\begin{aligned} \bar{I}^f(A) &= \int_0^1 \left( E^f [\tilde{A}^{1-\gamma_u} | F^{-1}(s|A)] \right)^\rho f(F^{-1}(s|A)|A) (F^{-1})'(s) ds \\ &= \int_0^1 \left( E^f [\tilde{A}^{1-\gamma_u} | F^{-1}(s|A)] \right)^\rho ds, \quad (f, F) = (\bar{f}, \bar{F}), (\hat{f}, \hat{F}) \end{aligned} \quad (30)$$

Differentiating (30) we obtain

$$\begin{aligned} \frac{\partial \bar{I}^f(A)}{\partial A} \frac{1}{\bar{I}^f(A)} &= \frac{1}{\bar{I}^f(A)} \int_Y (E^f[\tilde{A}^{1-\gamma_u}|y])^\rho f_A(y|A) dy \\ &= \int_0^1 \frac{(E^f[\tilde{A}^{1-\gamma_u}|F^{-1}(s|A)])^\rho}{\int_0^1 (E^f[\tilde{A}^{1-\gamma_u}|F^{-1}(\hat{s}|A)])^\rho d\hat{s}} \frac{f_A}{f} (F^{-1}(s|A)|A) ds. \end{aligned} \quad (31)$$

Combining (29) and (31) yields a useful characterization of ex ante inequality. Define

$$\Gamma^A(f|s) := \frac{(E^f[\tilde{A}^{1-\gamma_u}|F^{-1}(s|A)])^\rho}{\int_0^1 (E^f[\tilde{A}^{1-\gamma_u}|F^{-1}(\hat{s}|A)])^\rho d\hat{s}}; \quad (f, F) = (\bar{f}, \bar{F}), (\hat{f}, \hat{F}) \quad (32)$$

**Proposition 1** *Income inequality in the sense of Definition 4 is higher under information system  $\bar{f}$  than under information system  $\hat{f}$ , if and only if*

$$\int_0^1 \left[ \Gamma^A(\bar{f}|s) \frac{\bar{f}_A}{\bar{f}} (F^{-1}(s|A)|A) - \Gamma^A(\hat{f}|s) \frac{\hat{f}_A}{\hat{f}} (\hat{F}^{-1}(s|A)|A) \right] ds \geq 0, \quad (33)$$

holds for all  $A \in \mathcal{A}$ .

If relative risk aversion,  $\gamma_u$ , is equal to 1, expected individual income is linear in ability and, hence, income inequality is not affected by better information. To verify this claim we first observe that

$$\int_0^1 \frac{f_A}{f} (F^{-1}(s|A)|A) ds = \int_Y f_A(y|A) dy = 0. \quad (34)$$

**Proposition 2** *If  $\gamma_u = 1$ , income inequality does not depend on the chosen information system.*

Proof:  $\gamma_u = 1$  and equation (34) together imply that (33) is satisfied with equality for all  $A \in \mathcal{A}$ . Thus inequality of the income distribution is the same for any two information systems  $\bar{f}$  and  $\hat{f}$ .  $\square$

For  $\gamma_u = 1$  the individual effort level is not responsive to the information revealed by a signal (cf. (26)). As a consequence, the distribution of expected incomes across agents does not depend on the information system either. Yet, when  $\gamma_u$  differs from 1 a better information system may give rise to more or less income inequality.

**Theorem 1** Let  $\bar{f}$  and  $\hat{f}$  be two information systems with  $\bar{f} \succ_{\text{inf}} \hat{f}$ .

- (i) If  $\gamma_u \leq 1$ , the income distribution under  $\bar{f}$  is more unequal than the income distribution under  $\hat{f}$ .
- (ii) If  $\gamma_u \geq 1$ , the income distribution under  $\hat{f}$  is more unequal than the income distribution under  $\bar{f}$ .

Information affects the distribution of efforts at each date. From (26) we know that effort is increasing in the signal if  $\gamma_u \leq 1$ , and decreasing if  $\gamma_u \geq 1$ . Consider the case  $\gamma_u \leq 1$ . Under a better information system signals more accurately reflect the agents' talents. As a consequence, due to more favorable signals, agents with high talents tend to choose higher effort levels; and agents with low talents tend to choose lower effort levels. This mechanism produces more income inequality. Similarly, if  $\gamma_u \geq 1$  the mechanism works in reverse and reduces income inequality.

Let us briefly address the controversial issue of growth and inequality from the perspective of information systems. There is evidence that higher growth and lower inequality go hand in hand [see, e.g., Alesina and Rodrick (1994), Persson and Tabellini (1994)]. Yet, more recent empirical findings [e.g., Barro (2000), Forbes (2000), Rubinstein and Tsiddon (2002)] indicate that the relationship between inequality and growth is positive. This lack of consensus is often attributed to the large variations in inequality and growth, which makes it difficult to obtain robust relationship.

It may be possible to reconcile these empirical findings in our theoretical framework which takes information structures into account. Based on results we have derived in an earlier paper (Eckwert and Zilcha (2001b)) we argue that screening information induces a link between growth and income inequality. This link depends on preferences and, therefore, may differ across countries. It has been shown (Eckwert and Zilcha (2001b)) that when  $\rho$  is larger than 1 (hence  $\gamma_u$  is less than  $2 - (1 + \gamma_v)/\alpha$ ) better information enhances growth; and if  $\gamma_u$  is larger than 1, better information reduces the stock of human capital in all dates, hence reduces growth. Thus, given our above Theorem, when  $\gamma_u$  is larger than 1 lower growth and less inequality occur simultaneously under the more informative system. On

the other hand, if  $\gamma_u$  is less than  $2 - (1 + \gamma_v)/\alpha$ , higher growth and higher inequality go hand in hand as the information system improves. Thus, whenever  $\gamma_u \notin [2 - (1 - \gamma_v)/\alpha, 1]$ , better information entails that growth and inequality move in the same direction.

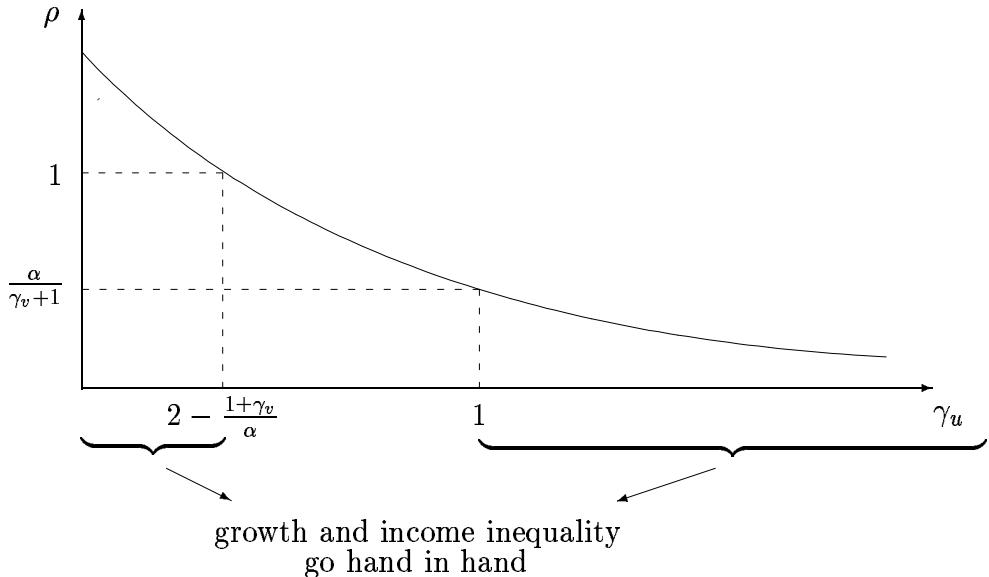


Figure 2.

#### 4 Information and Inequality with Risk Sharing

This section proceeds on the assumption that part of the uncertainty of an agent's ability is insurable. Let  $\tilde{A} = \tilde{A}_1 \cdot \tilde{A}_2$ , where  $\tilde{A}_1$  and  $\tilde{A}_2$  are stochastically independent random variables which take values in  $\mathcal{A}_1$  and  $\mathcal{A}_2$ . Before agents make decisions about effort they can insure the risk which is associated with the  $\tilde{A}_1$ - component of their (unknown) ability. The random variable  $\tilde{A}$  has the same properties as in the previous section. In particular, since individual ability is identically and independently distributed across the members of each generation, there exists no aggregate risk in our economy. As a consequence, the insurance market for the  $\tilde{A}_1$ -risk will be unbiased, i.e., the agents can share this risk on fair terms. In Section 3.1 the signals affected only uninsurable risks. In this section we assume that the

signals contain only information about the insurable risk factor  $\tilde{A}_1$ , i.e.,  $\tilde{A}_2$  and the signal are independent.<sup>7</sup>

In order to introduce the risk sharing market we need to assume that the  $\tilde{A}_1$ -component of individual ability is verifiable by the insurers. The random future income of each individual will then have an insurable component as well as an uninsurable component. Denote by  $\bar{A}_1(\nu_y)$  the expected value of  $\tilde{A}_1$  if the signal  $y$  has been observed,

$$\bar{A}_1(\nu_y) := \int_{\mathcal{A}} A_1 \nu_y(A) dA. \quad (35)$$

Since the insurance market is unbiased, all agents find it optimal to completely eliminate the  $\tilde{A}_1$ -risk from income in their second period of life. Thus the optimal saving and effort decisions of individual  $i \in G_t$  satisfy the following first order conditions

$$(1 + \bar{r}_t) u'_2((1 + \bar{r}_t)s^i) - u'_1(w_t \bar{A}_1(\nu_{y^i}) A_2 g(H_{t-1}, e^i) - s^i) = 0 \quad (A_2 \in \mathcal{A}_2) \quad (36)$$

$$v'(e^i) + w_t g_2(H_{t-1}, e^i) E[\tilde{A}(\nu_{y^i}) u'_1(w_t \tilde{A}(\nu_{y^i}) g(H_{t-1}, e^i) - s^i) | y^i] = 0 \quad (y^i \in Y), \quad (37)$$

where

$$\tilde{A}(\nu_{y^i}) := \bar{A}_1(\nu_{y^i}) \cdot \tilde{A}_2. \quad (38)$$

It is our aim to analyze the impact of information on income inequality if agents are able to share part of the uncertainty about their random ability. We are also interested in studying the role of risk sharing for income inequality for a *given* information system. Our next theorem deals with the former issue. It investigates whether better information about the insurable risk increases or decreases income inequality.

Using the functional specifications (23)-(26) the average income of an agent with ability  $A = A_1 \cdot A_2$  is

$$\begin{aligned} I_t^f(A_1, A_2) &= w_t \delta_t^\alpha \hat{g}(H_{t-1}) \left( E[\tilde{A}_2^{1-\gamma_u}] \right)^\rho A_2 \int_Y \left( E^f[\tilde{A}_1|y] \right)^\tau f(y|A_1) dy \\ &= w_t \delta_t^\alpha \hat{g}(H_{t-1}) \left( E[\tilde{A}_2^{1-\gamma_u}] \right)^\rho A_2 \int_0^1 \left( E^f[\tilde{A}_1|F^{-1}(s|A_1)] \right)^\tau ds, \end{aligned} \quad (39)$$

---

<sup>7</sup>In fact, the analysis in Section 3 can be understood as being conducted in the same stochastic framework as here with the signals containing only information about the uninsurable risk factor  $\tilde{A}_2$ .

where

$$\tau := 1 + \rho(1 - \gamma_u) = \frac{1 + \gamma_v}{\gamma_v + \alpha\gamma_u + (1 - \alpha)} > 0. \quad (40)$$

Since  $I_t^f(\cdot)$  is linear in  $A_2$  regardless of the information system, the elasticity of expected income with respect to  $A_1$  is now the relevant measure of inequality: the income distribution is more unequal under  $\bar{f}$  than under  $\hat{f}$  if  $\varepsilon[I_t^{\bar{f}}, A_1] \geq \varepsilon[I_t^{\hat{f}}, A_1]$  holds for all  $t \geq 0$  and  $A_1 \in \mathcal{A}_1$ .

Define

$$\Delta^{A_1}(f|s) := \frac{\left(E^f[\tilde{A}_1|F^{-1}(s|A_1)]\right)^{\tau}}{\int_0^1 \left(E^f[\tilde{A}_1|F^{-1}(\hat{s}|A_1)]\right)^{\tau} d\hat{s}}. \quad (41)$$

The same procedure as in Section 3 yields

**Proposition 3** *Income inequality is higher under information system  $\bar{f}$  than under information system  $\hat{f}$ , if and only if*

$$\int_0^1 \left[ \Delta^{A_1}(\bar{f}|s) \frac{\bar{f}_{A_1}}{\bar{f}} \left( \bar{F}^{-1}(s|A_1) \middle| A_1 \right) - \Delta^{A_1}(\hat{f}|s) \frac{\hat{f}_{A_1}}{\hat{f}} \left( \hat{F}^{-1}(s|A_1) \middle| A_1 \right) \right] ds \geq 0, \quad (42)$$

holds for all  $A_1 \in \mathcal{A}_1$ .

In the absence of risk sharing opportunities the impact of better information on income inequality was critically dependent on the risk aversion parameter  $\gamma_u$ . By contrast, if those risks which are affected by the signals can be insured on fair terms better information will always increase income inequality:

**Theorem 2** *Assume that an unbiased insurance market for the  $\tilde{A}_1$ -risk is available. Let  $\bar{f}$  and  $\hat{f}$  be two information systems with  $\bar{f} \succ_{\text{inf}} \hat{f}$ . The income distribution under  $\bar{f}$  is more unequal than the income distribution under  $\hat{f}$ .*

If the signals convey information about *insurable* risks more efficient screening (i.e., a better information system) results in more inequality regardless of the measure of relative risk aversion. In Section 3 we found that the effect of screening information about *non-insurable* risks on income inequality depends on the agents' attitudes towards risk. Why is risk sharing so critical for the link between income inequality and information?

In the absence of risk sharing arrangements agents use their effort decisions as a hedging instrument against talent risks: strongly risk-averse agents choose higher effort in response to a less favorable signal. This mechanism produces less income inequality under a more informative system. By contrast, moderately risk-averse agents choose higher effort when they receive a more favorable signal, which results in more income inequality.

When an unbiased risk sharing market exists, the implications of screening information on income inequality are different. The opportunity to obtain insurance against talent risks on fair terms obviously eliminates any incentives to use effort as a hedging device. However, under unbiased risk sharing arrangements, agents with favorable signals (i.e., high expected ability) obtain insurance on better terms than agents with unfavorable signals (i.e., low expected ability). This mechanism produces more income inequality under a more informative system, regardless of the agents' attitudes towards risk.

Unlike income inequality, economic growth is more intricately related to screening information. Even when risk sharing is possible, attitudes towards risk critically affect the link between growth and better information. Eckwert and Zilcha (2001b) found that in the framework of this paper better information enhances growth when  $\gamma_u$  is less than 1; and better information reduces growth when  $\gamma_u$  exceeds 1. Thus, in economies with low risk aversion ( $\gamma_u < 1$ ) information induced growth always comes at the cost of higher income inequality. For strongly risk-averse economies ( $\gamma_u > 1$ ), by contrast, our analysis suggests an inverse linkage between growth and inequality.

## 5 The Effect of Risk Sharing on Inequality

In this section we analyze the impact of risk sharing opportunities for the  $\tilde{A}_1$ -component of individual ability on income inequality. The comparison of the corresponding income distributions with and without risk sharing will be based on a given information system  $f$ . If no risk sharing opportunities are available the

average income of an agent with ability  $A = A_1 \cdot A_2$  is

$$\check{I}_t^f(A_1, A_2) = w_t \delta_t^\alpha \hat{g}(H_{t-1}) A_1 A_2 \left( E[\tilde{A}_2^{1-\gamma_u}] \right)^\rho \int_0^1 \left( E^f[\tilde{A}_1^{1-\gamma_u} | F^{-1}(s|A_1)] \right)^\rho ds. \quad (43)$$

If an insurance market for the  $\tilde{A}_1$ -risk exists average income is given by (39) which we restate here for convenience.

$$\hat{I}_t^f(A_1, A_2) = w_t \delta_t^\alpha \hat{g}(H_{t-1}) A_2 \left( E[\tilde{A}_2^{1-\gamma_u}] \right)^\rho \int_0^1 \left( E^f[\tilde{A}_1 | F^{-1}(s|A_1)] \right)^\tau ds. \quad (44)$$

Let us consider the case where  $\gamma_u \geq 1$  and, hence,  $\tau \leq 1$  (cf. (40)). If the system  $f$  is uninformative,  $f = f^0$ , the integrals in (43) and (44) do not depend on  $A_1$ . Thus

$$\check{\varepsilon}[I_t^{f^0}, A_1] = 1 \quad (45)$$

$$\hat{\varepsilon}[I_t^{f^0}, A_1] = 0, \quad (46)$$

where  $\check{\varepsilon}$  and  $\hat{\varepsilon}$  denote the income elasticities in the absence and in the presence of risk sharing opportunities, respectively.

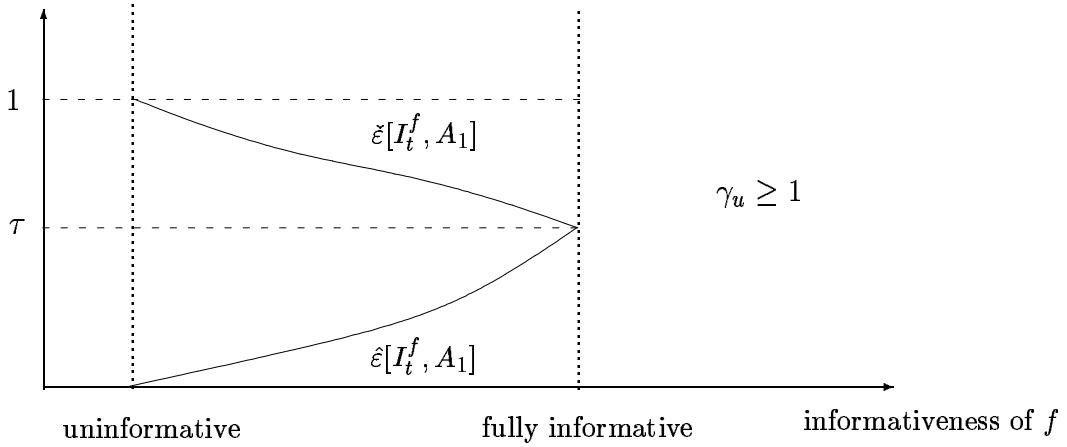


Figure 3.

Similarly, if the system  $f$  is fully informative,  $f = f^1$ , the signal  $F^{-1}(s|A_1)$  reveals the agent's talent  $A_1$  and, hence, equations (43) and (44) imply

$$\check{\varepsilon}[I_t^{f^1}, A_1] = \hat{\varepsilon}[I_t^{f^0}, A_1] = \tau. \quad (47)$$

According to Theorem 1,  $\check{\varepsilon}[I_t^f, A_1]$  declines as  $f$  becomes more informative; and according to Theorem 2,  $\hat{\varepsilon}[I_t^f, A_1]$  increases with better information.

Our discussion has shown that the availability of risk sharing opportunities reduces income inequality if  $\gamma_u \geq 1$ ; and that this effect is stronger in less well informed economies.

**Theorem 3** *Assume  $\gamma_u \geq 1$ , i.e., the economy is strongly risk averse. Under a market structure which allows agents to insure (part of) their talent risk on fair terms the income distribution will be less unequal than in the absence of such risk sharing opportunities. The impact of risk sharing on income inequality is weaker in economies with better information systems.*

If  $\gamma_u < 1$  the equations (45)-(47) continue to hold. In view of theorems 1 and 2 both  $\check{\varepsilon}[I_t^f, A_1]$  and  $\hat{\varepsilon}[I_t^f, A_1]$  increase as  $f$  becomes more informative. For some information systems, therefore, risk sharing may lead to higher income inequality (see Figure 4).<sup>8</sup>

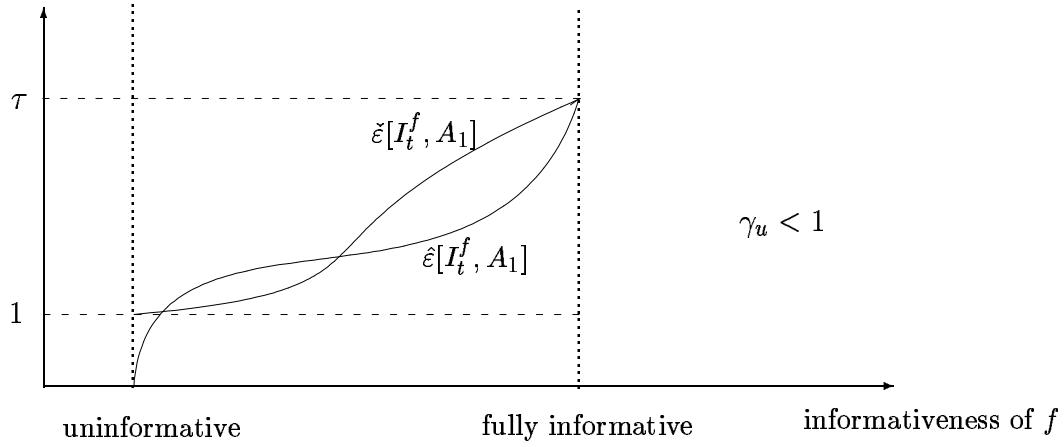


Figure 4.

---

<sup>8</sup>For  $\gamma_u < 1$  we can exclude the possibility of higher inequality due to risk sharing by imposing additional restrictions on the information system. E.g. the condition  $\frac{\partial}{\partial y}(\varepsilon[f(y|A_1), A_1]) \leq 1$ , all  $y, A_1$ , implies  $\check{\varepsilon}[I_t^f, A_1] \geq \hat{\varepsilon}[I_t^f, A_1]$ , all  $A_1$ .

## 6 Inequality vs. Welfare

It is often perceived by economists and other social scientists that less income inequality goes hand in hand with more welfare. Let us consider this issue from the perspective of our information analysis. We shall combine results on growth and welfare issues in an earlier paper [Eckwert and Zilcha (2001b)] with the results attained here. Assume first that *no risk sharing markets* exist. It was shown in the above paper that, when  $\gamma_u < 1$ , more information makes all generations better off in each competitive equilibrium. On the other hand, Theorem 1 here asserts that in this case more informative system results in *more* inequality. Thus, for  $\gamma_u < 1$  the link between income inequality and welfare is positive across countries which differ in their information systems only: the country with the better information system attains higher welfare levels and experiences more inequality.

Consider now economies *with* risk sharing markets. Using our result in Eckwert and Zilcha (2001b), when  $\gamma_u \geq 1/2$  more information results in lower welfare levels and (by Theorem 2 here) more inequality. Thus in this case inequality is inversely related to welfare across economies with different information systems.

## 7 Concluding Remarks

Education systems in all modern societies are based on screening mechanisms which generate information about the (unobservable) talent of young individuals. This paper is an attempt to analyze the implications of such mechanisms for the distribution of intragenerational income. A screening mechanism is modeled as an information system that allows the interpretation (in a Bayesian way) of signals which are specific to the agents.

Our analysis has shown that the implementation of a more efficient screening mechanism for individual talent will have effects on the inequality of the income distribution. These effects critically depend on the market structure of the economy. If the screening mechanism is applied to uninsurable risks, the income distribution will become more (less) unequal with more efficient screening if the economy is moderately (strongly) risk averse. Yet, if the screening mechanism applies to insurable risks, better screening always produces more income inequality. We have

also addressed the controversial question about the linkage between inequality and economic growth. For most parameter constellations our analysis suggests a positive link between growth and inequality if the screening process provides information about non-insurable risks. By contrast, when these risks are insurable, higher growth implies more (less) income inequality if the economy is moderately (strongly) risk-averse.

In our framework individuals make their decision about investment in education after they observe a signal correlated to their ability, but prior to knowing the rate of return on this investment, i.e., before the realization of their ‘type’. As a result ‘income’ can be defined at three points of time: (i) ex-ante income, i.e., expected income for each given level of ability  $A$ , (ii) expected income given the signal each individual observes, and (iii) ex-post income, i.e., the realized income when state of nature is known. We have considered here the ex-ante income distribution, but we are aware of the fact that our results may significantly change if we choose a different notion of income. Each type of inequality has a different conceptual meaning and it is not the place here to compare them due to the deep normative aspects it entails. We intend, however, to examine the issues discussed in this paper for the other notions of income as well.

To illustrate the significance of the underlying income concept for the properties of the equilibrium income distribution let us consider the subset  $D$  of all individuals with the same ability  $A$ . Under the ex ante specification (i) all individuals in this subset have the same income. Now consider the distribution of income after each person has observed an individual signal (specification (ii)). Obviously, agents in the subset  $D$  will almost surely have different incomes unless the information system is either fully informative (where the signal reveals the state) or uninformative (where the signals convey no information). A similar argument applies to the income specification (iii). Clearly we cannot expect that the results of our paper generalize to income concepts which correspond to the specifications (ii) or (iii).

## Appendix

Let us prove some preliminary results before we proceed with the proofs of the theorems.

Proof of Lemma 1: Define  $h(y|A, \hat{A}) := f(y|A)/f(y|\hat{A})$ . Obviously,  $h_y(y|A, \hat{A}) = 0$ ,  $\forall y$ , if  $A = \hat{A}$ . Also, by MLRP,  $h_y(y|A, \hat{A}) > 0$ ,  $\forall y$ , if  $A > \hat{A}$ . From this observation we conclude

$$0 \leq \frac{\partial}{\partial A} \left( h_y(y|A, \hat{A}) \right) \Big|_{A=\hat{A}} = \frac{\partial}{\partial y} \left( \frac{\partial h(y|A, \hat{A})}{\partial A} \Big|_{A=\hat{A}} \right) = \frac{\partial}{\partial y} \left( \frac{f_A(y|A)}{f(y|A)} \right),$$

which proves the claim.  $\square$

**Lemma 4** *Let  $\theta : X := [\underline{x}, \bar{x}] \rightarrow \mathbb{R}$  be an integrable function satisfying*

$$\int_{\underline{x}}^{\hat{x}} \theta(x) dx \leq 0; \quad \int_X \theta(x) dx = 0$$

*for all  $\hat{x} \in X$ . Then*

$$\int_X h(x)\theta(x) dx \stackrel{(\leq)}{\geq} 0$$

*holds for any differentiable monotone increasing (decreasing) function  $h : X \rightarrow \mathbb{R}$ .*

Proof: Integration by parts gives

$$\begin{aligned} \int_X h(x)\theta(x) dx &= h(x) \int_{\underline{x}}^x \theta(\hat{x}) d\hat{x} \Big|_{\underline{x}}^{\bar{x}} - \int_X h'(x) \int_{\underline{x}}^x \theta(\hat{x}) d\hat{x} dx \\ &= - \int_X h'(x) \int_x^{\bar{x}} \theta(\hat{x}) d\hat{x} dx. \end{aligned}$$

The last term is non-negative if  $h(x)$  is increasing; and it is non-positive if  $h(x)$  is decreasing.  $\square$

**Lemma 5** *Let  $\bar{f}$  and  $\hat{f}$  be two information systems with  $\bar{f} \succ_{\text{inf}} \hat{f}$ .*

(i)

$$\frac{\Gamma^A(\bar{f}|s'')}{\Gamma^A(\bar{f}|s')} \geq \frac{\Gamma^A(\hat{f}|s'')}{\Gamma^A(\hat{f}|s')}, \quad s'' \geq s', \quad A \in \mathcal{A} \quad (48)$$

*holds for  $\gamma_u \leq 1$ ,*

(ii)

$$\frac{\Gamma^A(\bar{f}|s'')}{\Gamma^A(\bar{f}|s')} \leq \frac{\Gamma^A(\hat{f}|s'')}{\Gamma^A(\hat{f}|s')}, \quad s'' \geq s', \quad A \in \mathcal{A} \quad (49)$$

holds for  $\gamma_u \geq 1$ .

Proof: (i) For  $\gamma_u \leq 1$  the information systems  $\bar{f}$  and  $\hat{f}$  satisfy MLRP with respect to the (transformed) state variable  $\tilde{A}^{1-\gamma_u}$ . Part (ii) in Definition 3 therefore implies the claim.

(ii) For  $\gamma_u \geq 1$  the information systems  $\bar{f}$  and  $\hat{f}$  satisfy the MLRP in reverse with respect to the state variable  $\tilde{A}^{1-\gamma_u}$ . In this case the inequality in part (ii) of Definition 3 reverses (see the Remark at the end of Section 2).  $\square$

**Corollary 1** Let  $\bar{f}$  and  $\hat{f}$  be two information systems with  $\bar{f} \succ_{\text{inf}} \hat{f}$ . Given any  $A \in \mathcal{A}$  and any increasing function  $V : [0, 1] \rightarrow \mathbb{R}$ ,

$$\int_0^1 V(s) \Gamma^A(\bar{f}|s) ds \stackrel{(\leq)}{\geq} \int_0^1 V(s) \Gamma^A(\hat{f}|s) ds$$

holds for  $\gamma_u \stackrel{(\geq)}{\leq} 1$ .

Proof: By Lemma 5, the densities  $\Gamma^A(f, \cdot)$ ,  $f = \bar{f}, \hat{f}$ , satisfy a variant of the MLRP in the sense of (48) for  $\gamma_u \leq 1$  and (49) for  $\gamma_u \geq 1$ . Therefore, the same reasoning as in the proof of Proposition 1 in Milgrom (1981) yields the result claimed in the corollary.  $\square$

Proof of Theorem 1: We apply the characterization in Proposition 1.

(i) According to Lemma 1,  $\frac{\bar{f}_A}{\bar{f}} \left( \bar{F}^{-1}(s|A) \middle| A \right)$  is monotone increasing in  $s$  for  $(f, F) = (\bar{f}, \bar{F}), (\hat{f}, \hat{F})$ . The validity of the condition in (33) is then immediate from the following assessment:

$$\begin{aligned} \int_0^1 \frac{\bar{f}_A}{\bar{f}} \left( \bar{F}^{-1}(s|A) \middle| A \right) \Gamma^A(\bar{f}|s) ds &\geq \int_0^1 \frac{\bar{f}_A}{\bar{f}} \left( \bar{F}^{-1}(s|A) \middle| A \right) \Gamma^A(\hat{f}|s) ds \\ &\geq \int_0^1 \frac{\hat{f}_A}{\hat{f}} \left( \hat{F}^{-1}(s|A) \middle| A \right) \Gamma^A(\hat{f}|s) ds \end{aligned}$$

In the first of the above inequalities we have used Corollary 1. The second inequality makes use of (34), Lemma 4, and the integral condition (18).

(ii) If  $\gamma_u \geq 1$ , the last two inequalities are reversed. Proposition 1 then implies the claim.  $\square$

**Lemma 6** *Let  $\bar{f}$  and  $\hat{f}$  be two information systems with  $\bar{f} \succ_{\text{inf}} \hat{f}$ .*

$$\frac{\Delta^{A_1}(\bar{f}|s'')}{\Gamma^A(\bar{f}|s')} \geq \frac{\Delta^{A_1}(\hat{f}|s'')}{\Delta^{A_1}(\hat{f}|s')} \quad (50)$$

*holds for all  $A_1 \in \mathcal{A}_\infty$ ,  $s'' \geq s'$ .*

Proof: Since the information systems  $\bar{f}$  and  $\hat{f}$  satisfy MLRP, with respect to the state variable  $\tilde{A}_1$ , (50) follows from part (ii) in Definition 3.  $\square$

**Corollary 2** *Let  $\bar{f}$  and  $\hat{f}$  be two information systems with  $\bar{f} \succ_{\text{inf}} \hat{f}$ . Given any increasing function  $V : [0, 1] \rightarrow \mathbb{R}$ ,*

$$\int_0^1 V(s) \Delta^{A_1}(\bar{f}|s) ds \geq \int_0^1 V(s) \Delta^{A_1}(\hat{f}|s) ds$$

*holds for all  $A_1 \in \mathcal{A}_\infty$ .*

Proof: By Lemma 6, the densities  $\Delta^{A_1}(f, \cdot)$ ,  $f = \bar{f}, \hat{f}$ , satisfy a variant of the MLRP in the sense of (50). The result follows by the same reasoning as in the proof of Proposition 1 in Milgrom (1981).  $\square$

Proof of Theorem 2: We apply the characterization in Proposition 3. Using Lemma 6 and Corollary 2, the proof proceeds as in part (i) of Theorem 1.  $\square$

## **References**

1. Aghion, P., 2002, *Schumpeterian Growth Theory and the Dynamics of Income Inequality*, *Econometrica* 70(3), 855-882.
2. Alesina, A. and Rodrick D., 1994, *Distributive Politics and Economic Growth*, *Quarterly Journal of Economics* 109(2), 465-490.
3. Azariadis, C. and Drazen, A., 1990, *Threshold Externalities in Economic Development*, *Quarterly Journal of Economics* 105, 501-526.
4. Barro, R. I., 2000, *Inequality and Growth in a Panel of Countries*, *Journal of Economic Growth* 5, 5-32.
5. Becker, G., 1964, *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*, Columbia University Press, New York.
6. Benabou, R., 1996, *Equity and Efficiency in Human Capital Investment: The Local Connection*, *Review of Economic Studies* 63, 237-264.
7. Blackwell, D., 1951, *Comparison of Experiments*, *Proceedings of the Second Berkeley Symposium on Mathematical Statistics*, 93-102.
8. Blackwell, D., 1953, *Equivalent Comparison of Experiments*, *Annals of Mathematical Statistics* 24, 265-272.
9. Diamond, P., 1965, *National Debt in a Neoclassical Growth Model*, *American Economic Review* 55, 1126-1150.
10. Demougin, D. and Fluet, C., 2001 *Ranking of Information Systems in Agency Models: An Integral Condition*, *Economic Theory* 17, 489-496.
11. Eckwert, B. and Zilcha, I., 2001a, *The Value of Information in Production Economies*, *Journal of Economic Theory* 100, 172-186.
12. Eckwert, B. and Zilcha, I., 2001b, *The Effect of Better Information on Growth and Welfare*, Working Paper #13-01, The Foerder Institute for Economic Research, Tel Aviv University.

13. Forbes, K. J., 2000 *A Reassessment of the Relationship Between Inequality and Growth*, American Economic Review 90(4), 865-887.
14. Galor, O. and Tsiddon, D., 1997, *The Distribution of Human Capital and Economic Growth*, Journal of Economic Growth 2, 93-124.
15. Galor, O. and Zeira, J., 1993, *Income Distribution and Macroeconomics*, Review of Economic Studies 60, 35-52.
16. Glomm, G. and Ravikumar, B., 1992, *Private Investment in Human Capital: Endogenous Growth and Income Inequality*, Journal of Political Economy 100, 818-834.
17. Green, J., 1981, *The Value of Information with Sequential Futures Markets*, Econometrica 49, 335-358.
18. Hassler, J. and Mora, V. R., 2000, *Intelligence, Social Mobility, and Growth*, American Economic Review 90(4), 888-908.
19. Hirshleifer, J., 1971, *The Private and Social Value of Information and the Reward to Incentive Activity*, American Economic Review 61, 561-574.
20. Hirshleifer, J., 1975, *Speculation and Equilibrium: Information, Risk and Markets*, Quarterly Journal of Economics 89, 519-542.
21. Juhn, C., Murphy, K. M. and Brooks, P., 1993, *Wage Inequality and the Rise in Return to Skill*, Journal of Political Economy 101(3), 410-442.
22. Kim, S. K., 1995 *Efficiency of an Information System in an Agency Model*, Econometrica 63(1), 89-102.
23. Louri, G., 1981, *Intergenerational Transfers and the Distribution of Earnings*, Econometrica 49(4), 843-867.
24. Milgrom, P. R., 1981, *Good News and Bad News: Representation Theorems and Applications*, Bell Journal of Economics 12, 380-391.

25. Orazem, P. and Tesfatsion, L., 1997, *Macrodynamic Implications of Income-Transfer Policies for Human Capital Investment and School Effort*, Journal of Economic Growth 2, 305-329.
26. Orosel, G. O., 1996, *Informational Efficiency and Welfare in the Stock Market*, European Economic Review 40, 1379-1411.
27. Persson, T. and Tabellini, G., 1994, *Is Inequality Harmful to Growth*, American Economic Review 84(3), 600-621.
28. Rubinstein, Y. and Tsiddon, D., 2002, *Coping With Technological Changes: The Role of Ability in Making Inequality so Persistent*, Working Paper, The Foerder Institute for Economic Research, Tel Aviv University.
29. Schlee, E., 2001, *The Value of Information in Efficient Risk Sharing Arrangements*, American Economic Review 91(3), 509-524.
30. Stiglitz, J., 1975, *The Theory of 'Screening', Education, and the Distribution of Income*, American Economic Review 65(3), 283-300.
31. Sylwester, K., 2002a, *A Model of Public Education and Income Inequality with a Subsistence Constraint*, Southern Economic Journal 69(1), 144-158.
32. Sylwester, K., 2002b, *Can Education Expenditures Reduce Income Inequality?*, Economics of Education Review 21, 43-52.
33. Viaene, J. M. and Zilcha, I., 2002 *Capital Markets Integration, Growth, and Income Distribution*, European Economic Review 46, 301-327.

# CESifo Working Paper Series

(for full list see [www.cesifo.de](http://www.cesifo.de))

---

- 903 Mika Widgrén, Enlargements and the Principles of Designing EU – Decision-Making Procedures, April 2003
- 904 Phornchanok Cumperayot, Dusting off the Perception of Risk and Returns in FOREX Markets, April 2003
- 905 Kai A Konrad, Inverse Campaigning, April 2003
- 906 Lars P. Feld and Stefan Voigt, Economic Growth and Judicial Independence: Cross Country Evidence Using a New Set of Indicators, April 2003
- 907 Giuseppe Bertola and Pietro Garibaldi, The Structure and History of Italian Unemployment, April 2003
- 908 Robert A.J. Dur and Otto H. Swank, Producing and Manipulating Information, April 2003
- 909 Christian Gollier, Collective Risk-Taking Decisions with Heterogeneous Beliefs, April 2003
- 910 Alexander F Wagner, Mathias Dufour, and Friedrich Schneider, Satisfaction not Guaranteed – Institutions and Satisfaction with Democracy in Western Europe, April 2003
- 911 Ngo Van Long, Raymond Riezman, and Antoine Soubeyran, Trade, Wage Gaps, and Specific Human Capital Accumulation, April 2003
- 912 Andrea Goldstein, Privatization in Italy 1993-2002: Goals, Institutions, Outcomes, and Outstanding Issues, April 2003
- 913 Rajshri Jayaraman and Mandar Oak, The Signaling Role of Municipal Currencies in Local Development, April 2003
- 914 Volker Grossmann, Managerial Job Assignment and Imperfect Competition in Asymmetric Equilibrium, April 2003
- 915 Christian Gollier and Richard Zeckhauser, Collective Investment Decision Making with Heterogeneous Time Preferences, April 2003
- 916 Thomas Moutos and William Scarth, Some Macroeconomic Consequences of Basic Income and Employment Subsidies, April 2003
- 917 Jan C. van Ours, Has the Dutch Miracle Come to an End?, April 2003

- 918 Bertil Holmlund, The Rise and Fall of Swedish Unemployment, April 2003
- 919 Bernd Huber and Marco Runkel, Optimal Design of Intergovernmental Grants under Asymmetric Information, April 2003
- 920 Klaus Wälde, Endogenous Business Cycles and Growth, April 2003
- 921 Ramon Castillo and Stergios Skaperdas, All in the Family or Public? Law and Appropriative Costs as Determinants of Ownership Structure, April 2003
- 922 Peter Fredriksson and Bertil Holmlund, Improving Incentives in Unemployment Insurance: A Review of Recent Research, April 2003
- 923 Bernard M.S. van Praag and Adam S. Booij, Risk Aversion and the Subjective Time Discount Rate: A Joint Approach, April 2003
- 924 Yin-Wong Cheung, Kon S. Lai, and Michael Bergman, Dissecting the PPP Puzzle: The Unconventional Roles of Nominal Exchange Rate and Price Adjustment, April 2003
- 925 Ugo Trivellato and Anna Giraldo, Assessing the ‘Choosiness’ of Job Seekers. An Exploratory Approach and Evidence for Italy, April 2003
- 926 Rudi Dornbusch and Stanley Fischer, International Financial Crises, April 2003
- 927 David-Jan Jansen and Jakob de Haan, Statements of ECB Officials and their Effect on the Level and Volatility of the Euro-Dollar Exchange Rate, April 2003
- 928 Mario Jametti and Thomas von Ungern-Sternberg, Assessing the Efficiency of an Insurance Provider – A Measurement Error Approach, April 2003
- 929 Paolo M. Panteghini and Gutterm Schjelderup, Competing for Foreign Direct Investments: A Real Options Approach, April 2003
- 930 Ansgar Belke, Rainer Fehn, and Neil Foster, Does Venture Capital Investment Spur Employment Growth?, April 2003
- 931 Assar Lindbeck, Sten Nyberg, and Jörgen W. Weibull, Social Norms and Welfare State Dynamics, April 2003
- 932 Myrna Wooders and Ben Zissimos, Hotelling Tax Competition, April 2003
- 933 Torben M. Andersen, From Excess to Shortage – Recent Developments in the Danish Labour Market, April 2003
- 934 Paolo M. Panteghini and Carlo Scarpa, Irreversible Investments and Regulatory Risk, April 2003
- 935 Henrik Jacobsen Kleven and Claus Thustrup Kreiner, The Marginal Cost of Public Funds in OECD Countries. Hours of Work Versus Labor Force Participation, April 2003

- 936 Klaus Adam, George W. Evans, and Seppo Honkapohja, Are Stationary Hyperinflation Paths Learnable?, April 2003
- 937 Ulrich Hange, Education Policy and Mobility: Some Basic Results, May 2003
- 938 Sören Blomquist and Vidar Christiansen, Is there a Case for Public Provision of Private Goods if Preferences are Heterogeneous? An Example with Day Care, May 2003
- 939 Hendrik Jürges, Kerstin Schneider, and Felix Büchel, The Effect of Central Exit Examinations on Student Achievement: Quasi-experimental Evidence from TIMSS Germany, May 2003
- 940 Samuel Bentolila and Juan F. Jimeno, Spanish Unemployment: The End of the Wild Ride?, May 2003
- 941 Thorsten Bayindir-Upmann and Anke Gerber, The Kalai-Smorodinsky Solution in Labor-Market Negotiations, May 2003
- 942 Ronnie Schöb, Workfare and Trade Unions: Labor Market Repercussions of Welfare Reform, May 2003
- 943 Marko Köthenbürger, Tax Competition in a Fiscal Union with Decentralized Leadership, May 2003
- 944 Albert Banal-Estañol, Inés Macho-Stadler, and Jo Seldeslachts, Mergers, Investment Decisions and Internal Organisation, May 2003
- 945 Kaniska Dam and David Pérez-Castrillo, The Principal-Agent Matching Market, May 2003
- 946 Ronnie Schöb, The Double Dividend Hypothesis of Environmental Taxes: A Survey, May 2003
- 947 Erkki Koskela and Mikko Puhakka, Stabilizing Competitive Cycles with Distortionary Taxation, May 2003
- 948 Steffen Huck and Kai A. Konrad, Strategic Trade Policy and Merger Profitability, May 2003
- 949 Frederick van der Ploeg, Beyond the Dogma of the Fixed Book Price Agreement, May 2003
- 950 Thomas Eichner and Rüdiger Pethig, A Microfoundation of Predator-Prey Dynamics, May 2003
- 951 Burkhard Heer and Bernd Süßmuth, Cold Progression and its Effects on Income Distribution, May 2003
- 952 Yu-Fu Chen and Michael Funke, Labour Demand in Germany: An Assessment of Non-Wage Labour Costs, May 2003

- 953 Hans Gersbach and Hans Haller, Competitive Markets, Collective Decisions and Group Formation, May 2003
- 954 Armin Falk, Urs Fischbacher, and Simon Gächter, Living in Two Neighborhoods – Social Interactions in the LAB, May 2003
- 955 Margarita Katsimi, Training, Job Security and Incentive Wages, May 2003
- 956 Clemens Fuest, Bernd Huber, and Jack Mintz, Capital Mobility and Tax Competition: A Survey, May 2003
- 957 Edward Castranova, The Price of ‘Man’ and ‘Woman’: A Hedonic Pricing Model of Avatar Attributes in a Synthetic World, June 2003
- 958 Laura Bottazzi and Marco Da Rin, Financing Entrepreneurial Firms in Europe: Facts, Issues, and Research Agenda, June 2003
- 959 Bruno S. Frey and Matthias Benz, Being Independent is a Great Thing: Subjective Evaluations of Self-Employment and Hierarchy, June 2003
- 960 Aaron Tornell and Frank Westermann, Credit Market Imperfections in Middle Income Countries, June 2003
- 961 Hans-Werner Sinn and Wolfgang Ochel, Social Union, Convergence and Migration, June 2003
- 962 Michael P. Devereux, Measuring Taxes on Income from Capital, June 2003
- 963 Jakob de Haan, Jan-Egbert Sturm and Bjørn Volkerink, How to Measure the Tax Burden on Labour at the Macro-Level?, June 2003
- 964 Harry Grubert, The Tax Burden on Cross-Border Investment: Company Strategies and Country Responses, June 2003
- 965 Kirk A. Collins and James B. Davies, Measuring Effective Tax Rates on Human Capital: Methodology and an Application to Canada, June 2003
- 966 W. Steven Clark, Using Micro-Data to Assess Average Tax Rates, June 2003
- 967 Christopher Heady, The ‘Taxing Wages’ Approach to Measuring the Tax Burden on Labour, June 2003
- 968 Michael P. Devereux and Alexander Klemm, Measuring Taxes on Income from Capital: Evidence from the UK, June 2003
- 969 Bernhard Eckwert and Itzhak Zilcha, The Effect of Better Information on Income Inequality, June 2003