Global poverty reduction and Pareto-improving redistribution

Chu, Angus C.

Institute of Economics, Academia Sinica

August 2009

Global Poverty Reduction and Pareto-Improving Redistribution

Angus C. Chu[*]

Institute of Economics, Academia Sinica

August 2009

Abstract

Can a transfer of wealth from the US to least developed countries be Pareto improving? We analyze this question in an open-economy innovation-driven growth model, in which the high-income (low-income) country produces innovative (homogenous) goods. We find that wealth redistribution to the low-income country simultaneously reduces global inequality and stimulates innovation through an increase in labor supply in the high-income country. Given that the market equilibrium of R&D-growth models is usually inefficient due to R&D externalities, the wealth redistribution may lead to a Pareto improvement, which occurs if the discount rate is sufficiently low or R&D productivity is sufficiently high.

Keywords**:** innovation-driven growth, wealth redistribution, Pareto improvement

JEL classification**:** O31, O41, F43

---

[*] Institute of Economics, Academia Sinica, Taipei, Taiwan. E-mail: angusccc@econ.sinica.edu.tw. I am grateful to Been-Lon Chen, Le-Yu Chen, Jang-Tin Guo, Chung-Cheng Lin, Shin-Kun Peng, Cheng-Chen Yang and seminar participants at Academia Sinica for helpful comments and suggestions. The usual disclaimer applies.

To require the President to develop and implement a comprehensive strategy to further the United States foreign policy objective of promoting the reduction of global poverty, the elimination of extreme global poverty, and the achievement of the Millennium Development Goal of reducing by one-half the proportion of people worldwide, between 1990 and 2015, who live on less than $1 per day.

Global Poverty Act of 2007

1. Introduction

A recent report by the World Bank shows that about 1.4 billion people live in extreme poverty as of 2005.[1] The World Bank defines extreme poverty as living on less than US$1.25 per day meaning that the victims of extreme poverty are often unable to meet basic needs for food, water, shelter, sanitation, and health care.[2] Some economists have proposed increasing anti-poverty aid from developed countries to reduce global poverty. For example, Sachs (2005) urges developed countries, such as the US, to set aside 0.7 percent of the gross national product for global poverty reduction. However, critiques are sometimes outraged by the potential tax burden on the citizens.[3] The purpose of this study is to show that this kind of global wealth redistribution may be Pareto improving through innovation and economic growth.

This paper develops an open-economy innovation-driven growth model to analyze the effects of cross-country wealth redistribution on innovation, economic growth and global welfare. Specifically, we extend the canonical quality-ladder model into a two-country setting. The high-income country (e.g. the US) produces innovative goods while the low-income country produces homogenous goods. Within this framework, a transfer of wealth to the low-income country stimulates innovation through an increase in labor supply in the high-income country. Intuitively, the wealth transfer increases the marginal utility of wealth of households in the high-income country and hence reduces their consumption of leisure. Therefore, when the high-income

[1] For more information, see http://go.worldbank.org/CUQLLRX1Q0.
[2] See, for example, Sachs (2005) for an excellent discussion on the problems of poverty in developing countries.
[3] See, for example, Cline (2008) and Schlafly (2008).

country owns a major share of wealth in the world, redistribution can simultaneously reduce global wealth inequality and increase growth through elastic labor supply. Given that the market equilibrium of R&D-based growth models is usually inefficient due to R&D externalities, the redistribution may improve both countries' welfare. We show that a Pareto improvement occurs if the discount rate is sufficiently low or R&D productivity is sufficiently high.

International transfers have been an important issue in international economics, and previous studies (to be discussed below) mostly focus on its welfare effects through trade. While the static trade effects are undoubtably important and have received careful analysis, the present study highlights the importance of a dynamic welfare effect of international transfers through growth. For this purpose, it is necessary to consider a growth-theoretic framework. Furthermore, the US is one of the countries at the world technology frontier so that innovation is arguably the most important channel to achieve sustainable growth. Therefore, we consider a model in which growth is driven by innovation. Also, there is supportive empirical evidence for a negative relationship between wealth and labor supply, which is the key mechanism behind the results of the present study.[4]

This paper also relates to the issue of R&D underinvestment. Empirical studies often find that the social return to R&D is much higher than the private return.[5] Jones and Williams (1998, 2000) apply these empirical estimates to an R&D-based growth model and find that the socially optimal level of R&D is at least two to four times higher than the market level. Therefore, overcoming this market failure of R&D underinvestment would stimulate innovation, increase R&D towards the social optimum and achieve a higher level of social welfare. Featuring this

[4] See, for example, Garcia-Penalosa and Turnovsky (2006) for a useful summary of empirical studies that find a negative relationship between wealth and labor supply. They also emphasize the importance of elastic labor supply on income inequality in the AK growth model, but wealth redistribution does not affect growth in their model.
[5] See Griliches (1992) for a review on this literature.

prominent market distortion, the R&D-based growth model with elastic labor supply is a suitable framework for analyzing the distortion-correcting effect of international transfers.

In the trade literature on international transfers, it is well-known since Samuelson (1947) that if there is no distortion and the equilibrium is stable, then the donating (aid-receiving) country must be worse off (better off). In the presence of distortions, Bhagwati *et al.* (1983) and others show that the donating (aid-receiving) country may become better off (worse off), and this phenomenon is known as the transfer paradox. Turunen-Red and Woodland (1988) consider a multilateral transfer and show that a Pareto improvement may occur but only if tariff distortions exist. The present study relates to these seminal studies by considering R&D underinvestment as a dynamic distortion that is inherent in the US economy and can be corrected by international transfers. In an overlapping generations (OLG) model, Galor and Polemarchakis (1987) show that the transfer paradox may occur due to the finite planning horizon of agents.[6] Shimomura (2007) relates Pareto-improving foreign aid to indeterminacy in a dynamic North-South model while Benarroch and Gaisford (2004) consider Pareto-improving foreign aid in a product-cycle model with *exogenous* innovation. The present study differs from these studies by analyzing the roles of *endogenous* innovation and R&D underinvestment on Pareto-improving transfers.

This paper also relates to the literature on inequality and growth.[7] The early studies of this literature focus on the effects of inequality on physical and human capital accumulation. For example, Bertola (1993), Alesina and Rodrik (1994) and Persson and Tabellini (1994) find that when inequality leads to redistribution through some political mechanism, the higher tax on capital income is detrimental to growth. In contrast, Galor and Zeira (1993) and Aghion and Bolton (1997) find that in the presence of credit constraints, redistribution may stimulate capital

---

[6] Cremers and Sen (2008) take into account transition dynamics and show that the possibility of a transfer paradox in the OLG model is robust.

[7] See Bertola *et al.* (2006) for an excellent textbook treatment of this literature.

accumulation. In a model in which growth is initially driven by physical capital and subsequently by human capital, Galor and Moav (2004) show that inequality increases (decreases) growth in the early (later) stages of development. While these studies focus on the effects of inequality on capital accumulation, the present study is related to a more recent sub-literature that analyzes the effects of inequality on innovation-driven growth. In this literature, the different channels through which inequality affects growth can be broadly assigned to two categories (a) supply of factor inputs for R&D and (b) demand for innovative goods (to be discussed below). Although the present study considers a two-country model, the global economy can also be viewed as a single country and the two countries can be relabeled as two types of households, who supply different labor inputs and own different shares of national wealth. In this case, redistribution across countries is isomorphic to redistribution across households.

Chou and Talmain (1996) develop a variety-expanding model with elastic labor supply and show that if and only if the elasticity of substitution between leisure and consumption differs from unity, wealth redistribution across households would affect growth through aggregate labor supply. While Chou and Talmain (1996) provide an early and interesting analysis on the effects of wealth redistribution on innovation-driven growth and social welfare, they point out that the growth rate and labor supply become non-stationary in their model under a non-unitary elasticity of substitution between leisure and consumption. In other words, wealth redistribution having an effect on growth is incompatible with balanced growth in the Chou-Talmain model. The present study continues to analyze the role of elastic labor supply on inequality and growth but allows for different types of labor based on the common perception that it is the supply of high-skill labor that contributes to growth. In this more realistic framework, redistribution affects growth under the conventional unit elasticity of substitution between leisure and consumption.

Garcia-Penalosa and Wen (2008) also explore the relationship between redistribution and growth through the supply of factor inputs for R&D. In particular, they analyze the effect of risk aversion on occupational choice. Their idea is that R&D entrepreneurship is a risky career; thus, the insurance effect of redistribution increases growth by providing more incentives for risk-averse agents to become R&D entrepreneurs. Our study complements Garcia-Penalosa and Wen (2008) by analyzing a related effect of redistribution on the supply of R&D labor.

While the above studies consider the effects of inequality on innovation-driven growth through the supply side, some studies analyze the demand side by allowing for non-homothetic preferences, e.g. indivisible consumption in Li (1998) and hierarchical preferences in Zweimuller (2000) and Foellmi and Zweimuller (2006).[8] Zweimuller (2000) considers the market effect of inequality (i.e. increasing inequality slows down the growth of market demand for innovative goods) and finds that wealth redistribution from wealthy to poor households increases growth. In contrast, Foellmi and Zweimuller (2006) consider both the market effect and the price effect (i.e. increasing inequality allows the innovative goods to be sold at a higher price) and find that the price effect dominates the market effect such that wealth redistribution from *poor to wealthy* households increases growth. While the demand-side result from Zweimuller (2000) is consistent with the supply-side results from Garcia-Penalosa and Wen (2008) and the present study, the result from Foellmi and Zweimuller (2006) is not. Therefore, it becomes an empirical question as to which effect dominates in reality.[9]

The rest of this study is organized as follows. Section 2 presents the model. Section 3 defines the equilibrium and derives the dynamic properties of the balanced-growth path (BGP)

[8] Some recent studies, such as Hatipoglu (2008) and Kiedaisch (2008), analyze the effects of patent protection on inequality and growth within this growth-theoretic framework of non-homothetic preferences.

[9] See Barro (2000) for a review on empirical studies that find different results on the growth-inequality relationship, and Barro also finds that the effects of inequality on growth are different across samples of countries.

and the distribution of wealth across countries. Section 4 analyzes the effects of redistribution on innovation, growth and welfare. Section 5 concludes.

2. The model

The underlying quality-ladder model is based on Grossman and Helpman (1991a).[10] We extend the Grossman-Helpman model into a simple asymmetric two-country setting, in which the high-income country produces innovative goods (e.g. skill-intensive manufacturing products) and the low-income country produces homogenous goods (e.g. agricultural products). This simple setup captures the reality that the level of skill and human capital in the US is higher than in the aid-receiving least developed countries. Also, we allow the two countries to own different shares of global wealth. As for the dynamics, we firstly show that the Euler equation implies a stationary distribution of consumption across countries. Then, given this stationary distribution of consumption, the aggregate economy always jumps to a unique and stable BGP. Finally, this balanced-growth behavior of the aggregate economy implies a stationary distribution of wealth across countries. Given that the quality-ladder growth model has been well-studied, the familiar components of the model will be briefly described while the new features will be described in more details.

2.1. Households

There are two countries indexed by a superscript $j \in \{h, l\}$. Country h is the high-income country, and country l is the low-income country. There is a unit continuum of representative households in each country. Households in country j have a lifetime utility function given by

[10] See, also, Aghion and Howitt (1992) and Segerstrom *et al.* (1990) for the other pioneering studies on the quality-ladder growth model.

(1) $$U^j = \int_0^\infty e^{-\rho t}(\ln C_t^j + \phi \ln \ell_t^j)dt \,.$$[11]

$\rho > 0$ is the discount rate. C_t^j is consumption, and ℓ_t^j is leisure. $\phi > 0$ is a preference parameter. Each household is endowed with one unit of time to allocate between leisure and labor supply. The households maximize utility subject to a sequence of budget constraints given by

(2) $$\dot{V}_t^j = R_t V_t^j + W_t^j (1 - \ell_t^j) - P_t C_t^j \,.$$

W_t^j is the wage rate in country *j*. V_t^j is the value of assets owned by households in country *j*. R_t is the nominal rate of return in the global financial market. P_t is the price of consumption goods that are tradable across countries at zero transportation cost for simplicity. The households' consumption-leisure tradeoff is

(3) $$W_t^j \ell_t^j = \phi P_t C_t^j \,.$$

From the households' intertemporal optimization, the familiar Euler equation is

(4) $$\frac{\dot{C}_t^j}{C_t^j} = \frac{\dot{C}_t}{C_t} = r_t - \rho \,,$$

where $r_t \equiv R_t - \dot{P}_t / P_t$ is the real interest rate, and $C_t \equiv C_t^h + C_t^l$ is global consumption. (4) implies that the distribution of consumption across the two countries is stationary.

2.2. Consumption and final goods

Consumption goods are produced by aggregating final goods from the two countries, and this sector is characterized by perfect competition.[12] The production function is $C_t = (Y_t^h)^{1-\alpha}(Y_t^l)^\alpha$,

[11] The more general iso-elastic utility function $U = \int e^{-\rho t}[(C_t \ell_t^\phi)^{1-\sigma} - 1]/(1-\sigma)dt$ also features a unitary elasticity of substitution between leisure and consumption. For simplicity, we focus on the more tractable log utility (i.e. $\sigma = 1$).

[12] Due to zero profit and zero transportation cost, it does not matter where consumption goods are produced.

where Y_t^h denotes final goods from country *h* and Y_t^l denotes final goods from country *l*. Final goods are also tradable subject to zero transportation cost. Final goods of country *l* are produced using domestic labor denoted by L_t, and the production function is $Y_t^l = L_t$. Again, this sector is perfectly competitive, and zero profit implies that the price of Y_t^l is equal to W_t^l. As for final goods of country *h*, Y_t^h is produced with a standard Cobb-Douglas aggregator over a continuum of non-tradable intermediates goods $X_t(i)$ for $i \in [0,1]$ given by

(5) $$Y_t^h = \exp\left(\int_0^1 \ln X_t(i) di\right).$$

This sector is perfectly competitive, and the producers take the output and input prices as given.

2.3. Intermediate goods

Country *h* produces a unit continuum of non-tradable intermediate goods indexed by $i \in [0,1]$. Each industry is dominated by a temporary monopolistic leader, who holds a patent on the latest invention and dominates the market until the next invention occurs. The production function is

(6) $$X_t(i) = z^{n_t(i)} H_{x,t}(i).$$

$z > 1$ is the exogenous size of technological improvement from each invention, and $n_t(i)$ is the number of inventions that have occurred in industry *i* as of time *t*. In other words, $z^{n_t(i)}$ is the level of technology in industry *i* at time *t*. $H_{x,t}(i)$ is country *h*'s production labor in industry *i*. The marginal cost of producing $X_t(i)$ is

(7) $$MC_{x,t}(i) = W_t^h / z^{n_t(i)}.$$

As commonly assumed in the literature, the current and former industry leaders engage in Bertrand competition. The familiar profit-maximizing price for the current leader is a constant markup over the marginal cost given by

(8) $$P_{x,t}(i) = z\,MC_{x,t}(i).$$[13]

2.4. R&D

Denote the value of an invention in industry *i* as $\widetilde{V}_t(i)$. Due to the Cobb-Douglas specification in (5), the amount of profits is the same across industries (i.e. $\pi_x(i) = \pi_x$ for $i \in [0,1]$). As a result, $\widetilde{V}_t(i) = \widetilde{V}_t$ for $i \in [0,1]$. Because inventions are the only assets in the model, their aggregate value equals the global value of assets owned by all households (i.e. $\widetilde{V}_t = V_t \equiv V_t^h + V_t^l$). The familiar no-arbitrage condition for V_t is

(9) $$R_t V_t = \pi_{x,t} + \dot{V}_t - \lambda_t V_t.$$

The left-hand side of (9) is the return on this asset. The right-hand side of (9) equals the sum of (a) the profit $\pi_{x,t}$ generated by this asset, (b) the potential capital gain $\dot{V}_t$, and (c) the expected capital loss $\lambda_t V_t$ due to creative destruction for which λ_t is the Poisson arrival rate of inventions.

In country *h*, there is a continuum of R&D entrepreneurs indexed by $k \in [0,1]$, and they hire R&D workers $H_{r,t}(k)$ to create inventions. The expected profit for entrepreneur *k* is

(10) $$\pi_{r,t}(k) = V_t \lambda_t(k) - W_t^h H_{r,t}(k).$$

The Poisson arrival rate of inventions for entrepreneur *k* is $\lambda_t(k) = \varphi H_{r,t}(k)$, where φ is R&D productivity. Because of free entry, entrepreneurs earn zero expected profit such that

---

[13] Li (2001) considers a CES production function. In this case, the monopolistic markup can be determined by either the quality step size or the elasticity of substitution depending on whether innovations are drastic or non-drastic.

(11) $$V_t \varphi = W_t^h .$$

This condition determines the allocation of workers between production and R&D in country *h*.

3. Decentralized equilibrium

In this section, we define the equilibrium and show that the economy is on a unique and stable BGP. The equilibrium is a sequence of prices $\{R_t, W_t^h, W_t^l, P_t, P_{x,t}(i), V_t^h, V_t^l, V_t\}_{t=0}^{\infty}$ and a sequence of allocations $\{Y_t^h, X_t(i), H_{x,t}(i), H_{r,t}(k), Y_t^l, L_t, \ell_t^h, \ell_t^l, C_t^h, C_t^l, C_t\}_{t=0}^{\infty}$. In each period,

a. households in country *j* choose $\{C_t^j, \ell_t^j\}$ to maximize (1) taking $\{R_t, W_t^j, P_t\}$ as given;

b. competitive consumption-goods firms produce $\{C_t\}$ to maximize profit taking prices as given;

c. competitive final-goods firms in country *h* produce $\{Y_t^h\}$ to maximize profit taking prices as given;

d. competitive final-goods firms in country *l* produce $\{Y_t^l\}$ to maximize profit taking prices as given;

e. the leader of industry *i* in country *j* produces $\{X_t(i)\}$ and chooses $\{P_{x,t}(i), H_{x,t}(i)\}$ to maximize profit according to the Bertrand competition and taking $\{W_t^h\}$ as given;

f. R&D entrepreneur *k* chooses $\{H_{r,t}(k)\}$ to maximize profit taking $\{W_t^h, V_t\}$ as given;

g. the market for consumption goods clears such that $C_t^h + C_t^l = C_t = (Y_t^h)^{1-\alpha}(Y_t^l)^{\alpha}$;

h. the market for final goods of country *h* clears such that $Y_t^h = Z_t H_{x,t}$, where aggregate technology is defined as $Z_t \equiv \exp\left(\int_0^1 n_t(i)di \ln z\right)$;

i. the market for final goods of country *l* clears such that $Y_t^l = L_t$;

j. the labor market in country *h* clears such that $H_{x,t} + H_{r,t} = 1 - \ell_t^h$;

k. the labor market in country *l* clears such that $L_t = 1 - \ell_t^l$; and

l. the value of national wealth adds up to global wealth such that $V_t^h + V_t^l = V_t$.

3.1. Dynamics of the aggregate economy

Define country *h*'s share of consumption in the world as $s_{c,t} \equiv C_t^h / C_t$. The Euler equation in (4) implies that this share is stationary across time (i.e. $s_{c,t} = s_c$ for all *t*). Given this stationary distribution of consumption across countries, we show that the aggregate economy always jumps to a unique and stable BGP. Let's define a new variable $\Omega_t \equiv P_t C_t / V_t$.

Lemma 1: *The law of motion for* Ω_t *is given by*

$$\frac{\dot{\Omega}_t}{\Omega_t} = (1 + \phi s_c - \alpha)\Omega_t - (\rho + \varphi). \tag{12}$$

Proof: See Appendix A.■

Figure 1 plots (12) and shows that Ω_t must jump to a unique steady state given by

$$\Omega^* = \frac{\rho + \varphi}{1 + \phi s_c - \alpha}. \tag{13}$$

Lemma 2 shows that a constant Ω_t implies a constant invention arrival rate λ_t. As a result, the equilibrium allocation of R&D labor is stationary and aggregate technology grows at a constant rate. The aggregate production function is

(14) $$C_t = (Z_t H_{x,t})^{1-\alpha}(L_t)^{\alpha},$$

where aggregate technology can be re-expressed as

(15) $$Z_t \equiv \exp\left(\int_0^1 n_t(i)di \ln z\right) = \exp\left(\int_0^t \lambda_s ds \ln z\right).$$

The second equality in (15) uses the law of large numbers. Differentiating the log of (15) with respect to time yields the growth rate of aggregate technology given by

(16) $$g_t \equiv \dot{Z}_t / Z_t = \lambda_t \ln z,$$

where $\lambda_t = \varphi H_{r,t}$ is the aggregate arrival rate of inventions. (14) implies that the balanced-growth rate of consumption is $(1-\alpha)g$.

Lemma 2: *The equilibrium allocation of R&D labor is stationary and aggregate technology grows at a constant rate.*

Proof: See Appendix A.■

3.2. Distribution of wealth

Define country h's share of global wealth as $s_{v,t} \equiv V_t^h / V_t$. We next show that the distribution of wealth across countries is stationary given the aggregate BGP.

Lemma 3: *The law of motion for* $s_{v,t}$ *is given by*

(17) $$\dot{s}_{v,t} = ((1+\phi s_c - \alpha)\Omega_t - \varphi)s_{v,t} - (s_c(1+\phi)\Omega_t - \varphi).$$

Proof: See Appendix A.■

From (13), $\Omega_t = \Omega^*$. Therefore, (17) is a one-dimensional differential equation that describes the potential evolution of $s_{v,t}$ given the initial $s_{v,0}$. Also, (13) implies $(1+\phi s_c - \alpha)\Omega^* - \varphi = \rho > 0$, so that the dynamic system is characterized by global instability. Therefore, the only solution consistent with long-run stability is $s_{v,t} = s_{v,0}$ for all *t*. Although $s_{v,t}$ is a state variable, $s_{v,0}$ is a stationary point by having s_c jump to its appropriate value at time 0.[14] In summary, the wealth distribution is stationary and equal to its initial distribution.

4. Effects of wealth redistribution on growth and welfare

In this section, we firstly derive the equilibrium allocation of R&D labor.[15] Then, we examine the effects of wealth redistribution implemented by a lump-sum transfer.[16]

Lemma 4: *The equilibrium allocations of leisure and R&D labor in country h are*

$$\ell^h = \frac{\phi}{1+\phi}\left(1 + \frac{\rho s_v}{\varphi}\right), \tag{18}$$

$$H_r = \frac{1}{z}\left(\frac{z-1}{1+\phi}\left(1 - \phi\frac{\rho s_v}{\varphi}\right) - \frac{\rho}{\varphi}\right). \tag{19}$$

Proof: See Appendix A.■

To ensure that $H_r > 0$, we impose a lower bound on R&D productivity.

Condition R (R&D productivity): $\varphi > \rho\left(\phi s_v + \frac{1+\phi}{z-1}\right)$.

---

[14] This value will be derived in the proof of Lemma 4 in Appendix A.
[15] The proof of Lemma 4 also provides the equilibrium allocations of other key variables.
[16] Financing the transfer through distortionary taxes would naturally lead to additional negative effects that reduce the parameter space for Pareto improvements.

The properties of equilibrium R&D labor are quite intuitive. An increase in either the markup z or R&D productivity φ improves the incentives for R&D and hence increases R&D labor. A larger discount rate decreases the present value of an invention and the incentives for R&D. As leisure becomes more important (i.e. a larger ϕ), labor supply decreases; as a result, R&D labor also decreases. Finally, a larger wealth share of country *h* reduces its households' marginal utility of wealth and their labor supply; consequently, R&D labor decreases.

Proposition 1: *A decrease in the wealth share of country h stimulates innovation and growth.*

Proof: See (16) and (19).■

We next analyze the relationship between global wealth inequality and growth. It can be shown that the variance of national wealth share is $\sigma_v = (s_v - 0.5)^2$. The square root of σ_v is the coefficient of variation of wealth that is a common measure of wealth inequality. Given that σ_v is an U-shape function in s_v and growth is decreasing in s_v, we have the following result.

Proposition 2: *When country h owns more (less) than half the wealth in the world, growth and global wealth inequality are negatively (positively) related.*

Proof: See Figure 2.■

We next examine the effects of global wealth redistribution on welfare. Specifically, we would like to know whether a decrease in the wealth share of country *h* can increase its households' welfare. Given the balanced-growth behavior of the economy, (1) simplifies to

(20) $$U^j = \frac{1}{\rho}\left(\ln C_0^j + (1-\alpha)\frac{g}{\rho} + \phi \ln \ell^j\right),$$

where $C_0^h = s_c C_0$, $C_0^l = (1-s_c)C_0$ and $C_0 = (Z_0 H_x)^{1-\alpha}(L)^{\alpha}$. Substituting these conditions into (20) and dropping the exogenous Z_0 yield

(21) $$\rho U^h = \ln s_c + \alpha \ln L + (1-\alpha)\ln H_x + (1-\alpha)\frac{g}{\rho} + \phi \ln \ell^h$$

for households in country *h*. As for households in country *l*, replace s_c by $1-s_c$ and ℓ^h by ℓ^l. Differentiating (21) with respect to s_v yields

(22) $$\rho\frac{\partial U^h}{\partial s_v} = \frac{1}{s_c}\underbrace{\left(\frac{\partial s_c}{\partial s_v}\right)}_{+} + \frac{\alpha}{L}\underbrace{\left(\frac{\partial L}{\partial s_v}\right)}_{+} + \frac{1-\alpha}{H_x}\underbrace{\left(\frac{\partial H_x}{\partial s_v}\right)}_{-} + \frac{1-\alpha}{\rho}\underbrace{\left(\frac{\partial g}{\partial s_v}\right)}_{-} + \frac{\phi}{\ell^h}\underbrace{\left(\frac{\partial \ell^h}{\partial s_v}\right)}_{+}.$$ [17]

A redistribution of wealth from country *h* to country *l* (i.e. a *decrease* in s_v) would decrease country *h* households' share of global consumption s_c and their leisure ℓ^h that lead to a welfare loss in country *h*. However, it would also increase H_x and H_r that raise global output and growth respectively; as a result, they lead to a welfare gain. As for $L = 1-\ell^l$, there are opposing effects from a smaller s_v. On one hand, the increase in $1-s_v$ would increase the leisure of households in country *l* and reduce their labor supply at a given wage. On the other hand, the increase in H_x increases the marginal product of L and hence W_t^l. It turns out that the wealth effect dominates the wage effect so that the overall effect on L is negative. Although there are different effects of s_v on U^h, Proposition 3 shows that if the discount rate ρ is sufficiently low or R&D productivity φ is sufficiently high, then the growth effect dominates other effects such that $\partial U^h / \partial s_v < 0$. In this case, country *h* surprisingly benefits from giving away some of their

[17] The signs of these derivatives will be derived in the proof of Proposition 3 in Appendix A.

wealth to country l because the equilibrium growth rate is inefficiently low. As for country l, Proposition 3 shows that if country h benefits from transferring some of their wealth to country l, then country l must also benefit from this transfer.

Proposition 3: *If ρ is sufficiently small or φ is sufficiently large, then wealth redistribution from country h to country l (i.e. a decrease in s_v) would increase the welfare of both countries.*

Proof: See Appendix A.■

To have a better understanding of Proposition 3, we derive the Pareto efficient allocation of R&D labor. We consider the case in which the social planner directly chooses the allocations to maximize $\theta U^h + (1-\theta)U^l$, where $\theta \in (0,1)$ is an exogenous preference weight on country h.

Lemma 5: *The Pareto efficient allocation of R&D labor is*

(23)
$$\widetilde{H}_r = 1 - \left(\theta \frac{\phi}{1-\alpha} + 1\right) \frac{\rho}{\varphi \ln z}.$$

Proof: See Appendix A.■

In the proof of Lemma 5, we also compare (19) and (23) and find that a small value of ρ / φ is a sufficient condition for $\widetilde{H}_r > H_r$ (i.e. R&D underinvestment), in which case the wealth transfer that stimulates innovation could lead to a Pareto improvement.

5. Conclusion

Although this study analyzes global wealth redistribution through the effects on innovation in the donating country, anti-poverty aid also carries other benefits, such as building up productive public infrastructure, for the aid-receiving countries.[18] Even focusing on the innovation effect in the donating country, this study suggests that international transfers can increase innovation and growth, reduce global inequality and possibly lead to a Pareto improvement. Therefore, critiques of anti-poverty aid may want to take into account the benefits for the US.

To derive closed-form solutions, we have kept the model simple and tractable. For example, we consider an exogenous trade pattern (i.e. the high-income country produces innovative goods while the low-income country produces homogenous goods) in order to highlight the effects of innovation in the high-income country. Furthermore, this simplification allows the open-economy model with two countries to be viewed as a closed-economy model with two types of households, so that the redistribution effects are readily comparable with the inequality-innovation literature that is based on a closed-economy setting. Also, the present study assumes that the aid-receiving country produces non-innovative goods without the possibility of imitation, technology transfer through multinational firms, and domestic innovation. This setup reflects the reality of providing anti-poverty aid to the least developed countries that have limited capacity to engage in the kind of (a) imitative R&D analyzed in Grossman and Helpman (1991b), (b) adaptive R&D for technology transfer analyzed in Dinopoulous and Segerstrom (2009) and (c) innovative R&D analyzed in Grossman and Lai (2004). Finally, the issue of scale effects is set aside by normalizing the supply of labor in the high-income country to unity so that it is the

[18] See, for example, Chatterjee *et al.* (2003) and Chatterjee and Turnovsky (2007) for recent studies on this issue.

share of labor devoted to R&D that determines growth as in the second-generation R&D-based endogenous-growth model.[19]

References

Aghion, P., and Bolton, P., 1997. A theory of trickle-down growth and development. *Review of Economic Studies* 64, 151-172.

Aghion, P., and Howitt, P., 1992. A model of growth through creative destruction. *Econometrica* 60, 323-351.

Alesina, A., and Rodrik, D., 1994. Redistributive politics and economic growth. *Quarterly Journal of Economics* 436, 465-490.

Barro, R., 2000. Inequality growth in a panel of countries. *Journal of Economic Growth* 5, 5-32.

Benarroch, M., and Gaisford J., 2004. Foreign aid, innovation, and technology transfer in a North–South model with learning-by-doing. *Review of Development Economics* 8, 361-378.

Bhagwati, J., Brecher, R., and Hatta, T., 1983. The generalized theory of transfers and welfare: bilateral transfers in a multilateral world. *American Economic Review* 83, 606-618.

Bertola, G., 1993. Factor shares and savings in endogenous growth. *American Economic Review* 83, 1184-1198.

Bertola, G., Foellimi, R., and Zweimuller, J., 2006. Income distribution in macroeconomic models. Princeton University Press.

Chatterjee, S., Sakoulis, G., and Turnovsky, S., 2003. Unilateral capital transfers, public investment, and economic growth. *European Economic Review* 47, 1077-1103.

Chatterjee, S., and Turnovsky, S., 2007. Foreign aid and economic growth: the role of flexible labor supply. *Journal of Development Economics* 84, 507-533.

[19] See Jones (1999) for an excellent discussion on scale effects in R&D-based growth models.

Chou, C., and Talmain, G., 1996. Redistribution and growth: Pareto improvements. *Journal of Economic Growth* 1, 505-523.

Cline, E., 2008. Obama's Global Poverty Act. *Capitalism Magazine*, April 3, 2008.

Cremers, E., and Sen, P., 2008. The transfer paradox in a one-sector overlapping generations model. *Journal of Economic Dynamics and Control* 32, 1995-2012.

Dinopoulos, E., and Segerstrom, P., 2009. Intellectual property rights, multinational firms and economic growth. *Journal of Development Economics*, forthcoming.

Foellmi, R., and Zweimuller, J., 2006. Income distribution and demand-induced innovations. *Review of Economic Studies* 73, 941-960.

Galor, O., and Moav, O., 2004. From physical to human capital accumulation: inequality and the process of development. *Review of Economic Studies* 71, 1001-1026.

Galor, O., and Polemarchakis, H., 1987. Intertemporal equilibrium and the transfer paradox. *Review of Economic Studies* 54, 147-156.

Galor, O., and Zeira, J., 1993. Income distribution and macroeconomics. *Review of Economic Studies* 60, 33-52.

Garcia-Penalosa, C., and Turnovsky, S., 2006. Growth and income inequality: a canonical model. *Economic Theory* 28, 25-49.

Garcia-Penalosa, C., and Wen, J., 2008. Redistribution and entrepreneurship with Schumpeterian growth. *Journal of Economic Growth* 13, 57-80.

Griliches, Z., 1992. The search for R&D spillovers. *Scandinavian Journal of Economics* 94, 29-47.

Grossman, G., and Helpman, E., 1991a. Quality ladders in the theory of growth. *Review of Economic Studies* 58, 43-61.

Grossman, G., and Helpman, E., 1991b. Endogenous product cycles. *Economic Journal* 101, 1241-1229.

Grossman, G., and Lai, E., 2004. International protection of intellectual property. *American Economic Review* 94, 1635-1653.

Hatipoglu, O., 2008. Patent, inequality and innovation-driven growth. *MPRA* Paper No. 7855.

Jones, C., 1999. Growth: with or without scale effects. *American Economic Review Papers and Proceedings* 89, 139-144.

Jones, C., and Williams, J., 1998. Measuring the social return to R&D. *Quarterly Journal of Economics* 113, 1119-1135.

Jones, C., and Williams, J., 2000. Too much of a good thing? The economics of investment in R&D. *Journal of Economic Growth* 5, 65-85.

Kiedaisch, C., 2008. Patent policy and income distribution. *Toulouse School of Economics* Working Paper.

Li, C., 1998. Inequality and growth: a Schumpeterian perspective. *University of Glasgow* Working Paper No. 9609.

Li, C., 2001. On the policy implications of endogenous technological progress. *Economic Journal* 111, C164-C179.

Persson, T., and Tabellini, G., 1994. Is inequality harmful for growth? *American Economic Review* 84, 600-621.

Sachs, J., 2005. The end of poverty: economic possibilities for our time. New York: Penguin Books.

Samuelson, P., 1947. Foundation of economic analysis. Cambridge, MA: Harvard University Press.

Schlafly, P., 2008. Obama's 0.7% solution for poverty gets pass from Senate Republicans. *Investor's Business Daily*, February 28, 2008.

Segerstrom, P., Anant, T., and Dinopoulos, E., 1990. A Schumpeterian model of the product life cycle. *American Economic Review* 80, 1077-1092.

Shimomura, K., 2007. A Pareto-improving foreign aid in a dynamic North–South model. In *Frontiers of Economics and Globalization*, edited by Beladi, H., and Choi, K., p. 131-153.

Turunen-Red, A., and Woodland, A., 1988. On the multilateral transfer problem: existence of Pareto improving international transfers. *Journal of International Economics* 25, 249-269.

Zweimuller, J., 2000. Schumpeterian entrepreneurs meet Engel's law: the impact of inequality on innovation-driven growth. *Journal of Economic Growth* 5, 185-206.

Appendix A

Proof of Lemma 1: Substituting (3) into (2) and aggregating the resulting expression for the two countries yield

(A1) $$\dot{V}_t = R_t V_t + W_t^h + W_t^l - (1+\phi) P_t C_t .$$

We next derive a relationship between W_t^l and $P_t C_t$. Combining $W_t^l \ell_t^l = \phi P_t C_t^l$ from (3) and $W_t^l (1-\ell_t^l) = W_t^l L_t = \alpha P_t C_t$ from the homogenous-goods share of output yields

(A2) $$W_t^l = [\phi(1-s_c) + \alpha] P_t C_t ,$$

where $1 - s_{c,t} \equiv C_t^l / C_t$ is stationary as implied by (4). Taking the log of $\Omega_t \equiv P_t C_t / V_t$ and then differentiating with respect to time yields

(A3) $$\frac{\dot{\Omega}_t}{\Omega_t} = \frac{\dot{P}_t}{P_t} + \frac{\dot{C}_t}{C_t} - \frac{\dot{V}_t}{V_t} .$$

Substituting (4), (11), (A1) and (A2) into (A3) yields (12).■

Proof of Lemma 2: The profit share of output is $\pi_{x,t} = (1-\alpha) P_t C_t (z-1)/z$. Given that Ω_t is constant from Lemma 1, $P_t C_t$ and V_t must grow at the same (possibly zero) rate. Applying this condition and (4) to (9) yields $V_t = \pi_{x,t} / (\rho + \lambda_t)$. Using these conditions, we can derive that

(A4) $$\Omega_t \equiv \frac{P_t C_t}{V_t} = \frac{1}{1-\alpha} \left(\frac{z}{z-1} \right) (\rho + \lambda_t) .$$

Therefore, if Ω_t is constant, then $\lambda_t = \varphi H_{r,t}$ must also be constant.■

Proof of Lemma 3: From its definition, the law of motion for $s_{v,t} \equiv V_t^h / V_t$ is given by

(A5) $$\frac{\dot{s}_{v,t}}{s_{v,t}} = \frac{\dot{V}_t^h}{\dot{V}_t^h} - \frac{\dot{V}_t}{\dot{V}_t} = \frac{W_t^h - (1+\phi)P_t C_t^h}{V_t^h} - \frac{W_t^h + W_t^l - (1+\phi)P_t C_t}{V_t},$$

where the second equality uses (2), (3) and (A1). Substituting (11) and (A2) into (A5) and then performing a few steps of mathematical manipulation yield

(A6) $$\dot{s}_{v,t} = \left((1+\phi s_c - \alpha)\frac{P_t C_t}{V_t} - \varphi \right) s_{v,t} - \left((1+\phi) s_c \frac{P_t C_t}{V_t} - \varphi \right).$$

Substituting $\Omega_t \equiv P_t C_t / V_t$ into (A6) yields (17).■

Proof of Lemma 4: Choosing W_t^h as the numeraire implies that $V_t = W_t^h / \varphi = 1/\varphi$ for all t so that $\dot{V}_t = 0$. The stationarity of the wealth distribution implies that $\dot{V}_t = \dot{V}_t^h = \dot{V}_t^l$. Imposing these conditions, (4) and (11) on (2) yields

(A7) $$P_t C_t^h = (\rho s_v + \varphi(1 - \ell_t^h))V_t.$$

(A8) $$P_t C_t^l = (\rho(1 - s_v) + \varphi(1 - \ell_t^l)\omega_t)V_t,$$

where $\omega_t \equiv W_t^l / W_t^h = W_t^l$ is the relative wage (to be determined below). Substituting (11), (A7) and (A8) into (3) yields

(A9) $$\ell_t^h = \frac{\phi}{1+\phi}\left(1 + \frac{\rho s_v}{\varphi}\right),$$

(A10) $$\ell_t^l = \frac{\phi}{1+\phi}\left(1 + \frac{\rho(1-s_v)}{\varphi \omega_t}\right).$$

Country h's labor share of output is $W_t^h H_{x,t} = (1-\alpha)P_t C_t / z$, and the profit share of output is $\pi_{x,t} = (1-\alpha)P_t C_t (z-1)/z$. Applying these conditions, $V_t = \pi_{x,t}/(\rho+\lambda_t)$ and $\lambda_t = \varphi H_{r,t}$ to (11) yields

(A11) $$(z-1)H_{x,t} = H_{r,t} + \rho/\varphi .$$

Combining (A9), (A11) and $H_{x,t} + H_{r,t} = 1 - \ell_t^h$ yields

(A12) $$H_{r,t} = \frac{1}{z}\left(\frac{z-1}{1+\phi}\left(1-\phi\frac{\rho s_v}{\varphi}\right) - \frac{\rho}{\varphi}\right),$$

(A13) $$H_{x,t} = \frac{1}{z}\left(\frac{1}{1+\phi}\left(1-\phi\frac{\rho s_v}{\varphi}\right) + \frac{\rho}{\varphi}\right).$$

Combining $W_t^h H_{x,t} = (1-\alpha)P_t C_t / z$ and $W_t^l L_t = \alpha P_t C_t$ yields

(A14) $$\omega_t = \frac{z\alpha}{1-\alpha}\left(\frac{H_{x,t}}{L_{x,t}}\right) = \left(\frac{1}{1-\alpha}\right)\left(\alpha\left(1+\frac{\rho}{\varphi}\right) + \phi\frac{\rho(1-s_v)}{\varphi}\right),$$

where the last equality is obtained by using $L_t = 1 - \ell_t^l$, (A10) and (A13). Finally, combining (13), (17) and $\dot{s}_{v,t} = 0$ yields

(A15) $$s_c = \frac{(1-\alpha)(\rho s_v + \varphi)}{(1+\phi)(\rho+\varphi) - \phi(\rho s_v + \varphi)}.$$

Note that if s_v equals one, then $s_c = 1-\alpha$. Furthermore, as s_v decreases, s_c also decreases.■

Proof of Proposition 3: Using (A15), we can show that

(A16) $$\frac{\partial \ln s_c}{\partial s_v} = \frac{\rho}{\rho s_v + \varphi} + \frac{\phi\rho}{(1+\phi)(\rho+\varphi) - \phi(\rho s_v + \varphi)} > 0 .$$

Also, $\partial \ln s_c / \partial s_v$ approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Using (A13), we can show that

(A17) $$(1-\alpha)\frac{\partial \ln H_x}{\partial s_v} = -\left(\frac{\phi}{1+\phi}\frac{\rho(1-\alpha)}{\varphi}\right)\Bigg/\left(\frac{1}{1+\phi}\left(1-\phi\frac{\rho s_v}{\varphi}\right)+\frac{\rho}{\varphi}\right) < 0 .$$

Note that Condition R implies $1-\phi\rho s_v/\varphi > 0$. Also, $\partial \ln H_x/\partial s_v$ approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Using (A12), we can show that

(A18) $$\frac{1-\alpha}{\rho}\frac{\partial g}{\partial s_v} = (1-\alpha)\left(\frac{\varphi \ln z}{\rho}\right)\frac{\partial H_r}{\partial s_v} = -(1-\alpha)\frac{\phi}{1+\phi}\left(\frac{z-1}{z}\right)\ln z < 0 ,$$

which is *independent* of ρ and φ. Using (A9), we can show that

(A19) $$\phi\frac{\partial \ln \ell^h}{\partial s_v} = \phi\frac{\rho}{\varphi}\Bigg/\left(1+\frac{\rho s_v}{\varphi}\right) > 0 ,$$

which approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Using (A10) and $L = 1-\ell^l$, we can show that

(A20) $$\alpha\frac{\partial \ln L}{\partial s_v} = \frac{\alpha\rho\phi}{\omega\varphi-\rho\phi(1-s_v)}\left(1+\left(\frac{1-s_v}{\omega}\right)\frac{\partial \omega}{\partial s_v}\right).$$

As for $\partial\omega/\partial s_v$, we can use (A14) to show that

(A21) $$\frac{\partial \omega}{\partial s_v} = -\frac{1}{1-\alpha}\left(\frac{\rho\phi}{\varphi}\right) < 0 .$$

Substituting (A14) and (A21) into (A20) shows that $\partial \ln L/\partial s_v$ is positive and approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Therefore, if either ρ is sufficiently low or φ is sufficiently large, then the growth effect of wealth redistribution dominates the other effects such that country *h* benefits from transferring some wealth to country *l*. As for country *l*'s welfare,

(A22) $$\rho\frac{\partial U^l}{\partial s_v} = \underbrace{-\frac{1}{1-s_c}\left(\frac{\partial s_c}{\partial s_v}\right)}_{-} + \frac{\alpha}{L}\underbrace{\left(\frac{\partial L}{\partial s_v}\right)}_{+} + \frac{1-\alpha}{H_x}\underbrace{\left(\frac{\partial H_x}{\partial s_v}\right)}_{-} + \frac{1-\alpha}{\rho}\underbrace{\left(\frac{\partial g}{\partial s_v}\right)}_{-} + \frac{\phi}{\ell^l}\underbrace{\left(\frac{\partial \ell^l}{\partial s_v}\right)}_{-}.$$

Comparing (22) and (A22) shows that $\partial U^h/\partial s_v < 0$ is a sufficient condition for $\partial U^l/\partial s_v < 0$.■

Proof of Lemma 5: The social planner chooses C_0^h, C_0^l, ℓ^h, ℓ^l and H_x to maximize

$$\text{(A23)}\qquad \theta U^h + (1-\theta)U^l = \frac{1}{\rho}\left(\theta \ln C_0^h + (1-\theta)\ln C_0^l + \left(\frac{1-\alpha}{\rho}\right)g + \theta\phi \ln \ell^h + (1-\theta)\phi \ln \ell^l\right)$$

subject to: (a) $C_0^h + C_0^l = C_0 = (Z_0 H_x)^{1-\alpha}(L)^{\alpha}$, (b) $g = (\varphi \ln z)H_r$, (c) $H_x + H_r = 1 - \ell^h$ and (d) $L = 1 - \ell^l$. Denote the Lagrange function by $\Gamma = \rho(\theta U^h + (1-\theta)U^l) + \mu(C_0 - C_0^h - C_0^l)$, where μ is the Lagrange multiplier. The first-order conditions are

$$\text{(A24)}\qquad \frac{\partial \Gamma}{\partial C_0^h} = \frac{\theta}{C_0^h} - \mu = 0,$$

$$\text{(A25)}\qquad \frac{\partial \Gamma}{\partial C_0^l} = \frac{1-\theta}{C_0^l} - \mu = 0,$$

$$\text{(A26)}\qquad \frac{\partial \Gamma}{\partial \ell^h} = -(1-\alpha)\left(\frac{\varphi \ln z}{\rho}\right) + \theta\left(\frac{\phi}{\ell^h}\right) = 0,$$

$$\text{(A27)}\qquad \frac{\partial \Gamma}{\partial \ell^l} = (1-\theta)\left(\frac{\phi}{\ell^l}\right) - \mu\alpha\left(\frac{C_0}{1-\ell^l}\right) = 0,$$

$$\text{(A28)}\qquad \frac{\partial \Gamma}{\partial H_x} = -(1-\alpha)\left(\frac{\varphi \ln z}{\rho}\right) + \mu(1-\alpha)\left(\frac{C_0}{H_x}\right) = 0.$$

(A24) and (A25) imply that $\mu = 1/C_0$. Then, combining this condition with $H_x + H_r = 1 - \ell^h$, (A26) and (A28) yields (23). Comparing (19) and (23) yields

$$\text{(A29)}\qquad \widetilde{H}_r > H_r \Leftrightarrow \underbrace{\left(1 - \left(\frac{1}{1+\phi}\right)\frac{z-1}{z}\right)}_{A>0} > \underbrace{\left(\theta \frac{\phi}{1-\alpha}\frac{1}{\ln z} + \frac{z - \ln z}{z \ln z} - \frac{\phi}{1+\phi}\frac{z-1}{z}s_v\right)}_{B}\frac{\rho}{\varphi}.$$

There are two cases to consider. First, if $B > 0$, then $\rho/\phi < A/B$ is equivalent to $\widetilde{H}_r > H_r$. Second, if $B < 0$, then $\widetilde{H}_r > H_r$ always holds. This second case becomes more likely to occur as z increases because B is decreasing in z.■

Figure 1: Phase diagram

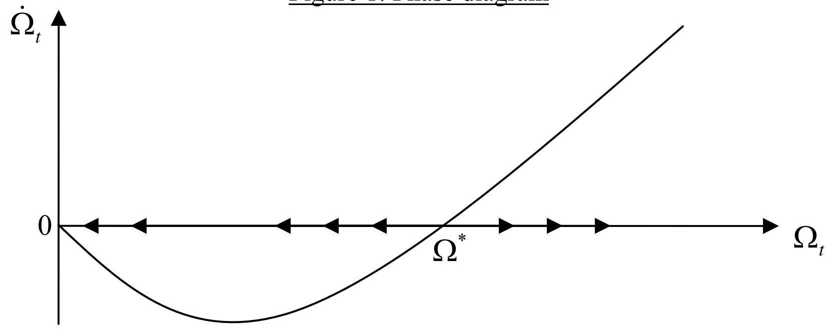

Figure 2: Global wealth inequality and growth