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GLOBAL POVERTY REDUCTION AND PARETO-IMPROVING REDISTRIBUTION

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Can a transfer of wealth from the United States to the least developed countries be Pareto improving? We analyze this question in an open-economy R&D-based growth model, in which the high-income (low-income) country produces innovative (homogeneous) goods. We find that wealth redistribution to the low-income country simultaneously reduces global inequality and increases economic growth through an increase in labor supply in the high-income country. Given that the market equilibrium of R&D-based 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: Economic Growth, R&D, Pareto-Improving Redistribution

> 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 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

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countries to reduce global poverty. For example, Sachs (2005) urges developed countries, such as the United States, to set aside 0.7% of gross national product for global poverty reduction. However, critices 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 R&D-based 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 United States) produces innovative goods, whereas the low-income country produces homogeneous 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 country owns a major share of the wealth in the world, redistribution can simultaneously reduce global 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. Although 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 economic growth. For this purpose, it is necessary to consider a growth-theoretic framework. Furthermore, the United States is a country at the world technology frontier, so that innovation is one of the most important channels for achieving growth in the long run. Therefore, we consider an innovation-driven growth model. 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 toward the social optimum, and achieve a higher level of social welfare. Featuring this 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.

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In the trade literature on international transfers, it has been 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). 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 U.S. economy and can be corrected by international transfers. In an overlapping-generations (OLG) model, Galor and Polemarchakis (1987) show that the transfer paradox may also occur due to the finite planning horizon of agents.[6] Benarroch and Gaisford (2004) consider Pareto-improving foreign aid in a North–South product-cycle model in which production exhibits learning by doing and new products are introduced exogenously over time.[7] The present study differs from these interesting studies in analyzing the important effects of market-based innovations and R&D underinvestment on Pareto-improving transfers.

This paper also relates to the literature on inequality and growth.[8] The early studies in 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 political mechanisms, 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 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. Whereas these studies focus on the effects of inequality on capital accumulation, the present study is related to a more recent subliterature 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: (i) supply of factor inputs for R&D and (ii) 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 will affect growth through aggregate labor supply. Although 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 nonstationary in their model under nonunitary

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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 effect 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 unitary 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.

Whereas 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 nonhomothetic preferences, e.g., indivisible consumption in Li (1998) and hierarchical preferences in Zweimuller (2000) and Foellmi and Zweimuller (2006). 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, so that wealth redistribution *from poor to wealthy* households increases growth. Although 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 which effect dominates in reality.[9]

Although the present study focuses on the effects of redistribution on innovation in the donating country, antipoverty aid also carries other potential benefits, such as building up productive public infrastructure, for the aid-receiving countries.[10] As for the empirical impacts of foreign aid on the aid-receiving countries, existing studies present inconclusive results.[11] For example, using instrumental-variable techniques, Boone (1996) finds that foreign aid neither increases investment significantly nor reduces poverty, and it only increases unproductive public consumption. A subsequent and influential study by Burnside and Dollar (2000) suggests that the impact of aid is conditional on policy. In summary, they find that foreign aid has a positive impact on growth, but only in developing countries that implement good policies. However, this empirical finding has been challenged for being data-dependent. For example, Easterly et al. (2004) show that adding new data that were unavailable to Burnside and Dollar (2000) would render their results insignificant. In summary, whether or not foreign aid would stimulate growth

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in developing countries remains an unresolved issue. However, these inclusive empirical findings do not disturb the main implication of this study, which focuses on the potential benefit of aid through increasing labor supply and innovation *in the donating country*.

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) and the distribution of wealth across countries. Section 4 analyzes the effects of redistribution on innovation, growth and welfare. Section 5 provides a discussion on the theoretical framework, and the final section concludes.

2. THE MODEL

The underlying quality-ladder model is based on Grossman and Helpman (1991b).[12] 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 homogeneous goods (e.g., agricultural products). This setup captures the reality that the level of skill and human capital in the United States is higher than that 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 first 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, and the new features will be described in more detail.

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[13]

$$U^j = \int_0^\infty e^{-\rho t}\left(\ln C_t^j + \phi \ln \ell_t^j\right) dt, \tag{1}$$

where $\rho > 0$ is the discount rate, C_t^j is consumption, and ℓ_t^j is leisure. $\phi > 0$ is a preference parameter on leisure. Each household is endowed with one unit of time to allocate between leisure and labor supply. Households maximize utility subject to

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

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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. Households' consumption–leisure tradeoff is

$$W_t^j \ell_t^j = \phi P_t C_t^j. \tag{3}$$

From households' intertemporal optimization, the familiar Euler equation is

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

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. Equation (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.[14] The production function is $C_t = (Y_t^h)^{1-\alpha}(Y_t^l)^{\alpha}$, 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 by a standard Cobb–Douglas aggregator over a unit continuum of nontradable differentiated intermediates goods $X_t(i)$:

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

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

2.3. Intermediate Goods

Country h produces a continuum of nontradable 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

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

$z > 1$ 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

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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

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

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 (given by the step size z) over the marginal cost:[15]

$$P_{x,t}(i) = zMC_{x,t}(i). \tag{8}$$

2.4. R&D

Denote the value of an invention in industry i as $V_t(i)$. Owing to the Cobb–Douglas specification in (5), the amount of profits is the same across industries (i.e., $\pi_{x,t}(i) = \pi_{x,t}$ for $i \in [0, 1]$). As a result, $V_t(i) = V_t$ in a symmetric equilibrium in which the arrival rate of innovation is equal across industries. Because inventions are the only assets in the model, their aggregate value equals the global value of assets owned by all households (i.e., $V_t = V_t^h + V_t^l$). The familiar no-arbitrage condition for V_t is

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

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

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

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

The Poisson arrival rate of innovation 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, so that

$$V_t \varphi = W_t^h. \tag{11}$$

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

3. DECENTRALIZED EQUILIBRIUM

In this section, we define the market equilibrium and show that the economy is on a unique and stable BGP. The equilibrium is a time path 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 time path of market allocations

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$\{Y_t^h, X_t(i), H_{x,t}(i), H_{r,t}(k), Y_t^l, L_t, \ell_t^h, \ell_t^l, C_t^h, C_t^l, C_t\}_{t=0}^{\infty}$. Also, at each instant of time,

- households in country j choose $\{C_t^j, \ell_t^j\}$ to maximize utility, taking $\{R_t, P_t, W_t^j\}$ as given;
- competitive consumption-goods firms produce $\{C_t\}$ to maximize profit, taking prices as given;
- competitive final-goods firms in country h produce $\{Y_t^h\}$ to maximize profit, taking prices as given;
- competitive final-goods firms in country l produce $\{Y_t^l\}$ to maximize profit, taking prices as given;
- the leader of industry i in country h 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;
- R&D entrepreneur k chooses $\{H_{r,t}(k)\}$ to maximize expected profit, taking $\{W_t^h, V_t\}$ as given;
- the market for consumption goods clears such that $C_t^h + C_t^l = C_t = (Y_t^h)^{1-\alpha}(Y_t^l)^{\alpha}$;
- 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 $Z_t \equiv \exp(\int_0^1 n_t(i)di \ln z)$;
- the market for final goods of country l clears such that $Y_t^l = L_t$;
- the labor market in country h clears such that $H_{x,t} + H_{r,t} = 1 - \ell_t^h$;
- the labor market in country l clears such that $L_t = 1 - \ell_t^l$; and
- 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 global consumption 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 us 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. ■

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 if Ω_t is constant, then the arrival rate λ_t of innovation will also be constant. As a result, the equilibrium allocation of R&D labor is stationary, and

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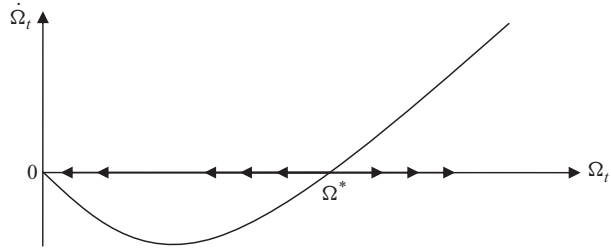


FIGURE 1. Phase diagram.

aggregate technology grows at a constant rate. The aggregate production function is

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

where aggregate technology can be reexpressed as

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

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,

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

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

LEMMA 2. *The equilibrium allocation of R&D labor is stationary.*

Proof. See Appendix. ■

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 is stationary given the aggregate BGP.

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

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

Proof. See Appendix. ■

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 that $(1+\phi s_c - \alpha)\Omega^* - \varphi = \rho > 0$, so 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

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by having s_c jump to its appropriate value at time 0.[16] 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 first derive the equilibrium allocation of R&D labor.[17] Then we examine the effects of wealth redistribution implemented by a lump-sum transfer.[18]

LEMMA 4. *The 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. ■

Condition R (R&D productivity) $\varphi > \rho[\phi s_v + (1+\phi)/(z-1)]$. Condition R imposes a lower bound on R&D productivity to ensure that $H_r > 0$. As for the properties of equilibrium R&D labor, they are in fact quite intuitive. An increase in either markup z or R&D productivity φ improves the incentives for R&D and hence increases R&D labor. A higher discount rate reduces the market 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, which is a common measure of wealth inequality. Given that σ_v is a U-shaped 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

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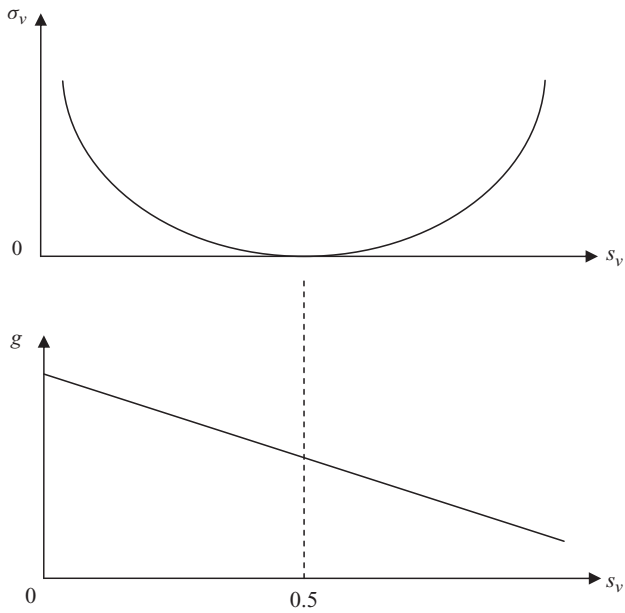


FIGURE 2. Global wealth inequality and growth.

economy, (1) simplifies to

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

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 yields

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

for households in country h. As for households in country l, simply replace s_c by $1 - s_c$ and ℓ^h by ℓ^l. Differentiating (21) with respect to s_v yields[19]

$$\rho\frac{\partial U^h}{\partial s_v} = \frac{1}{s_c}\underbrace{\left(\frac{\partial s_c}{\partial s_v}\right)}_{>0} + \frac{\alpha}{L}\underbrace{\left(\frac{\partial L}{\partial s_v}\right)}_{>0} + \frac{1-\alpha}{H_x}\underbrace{\left(\frac{\partial H_x}{\partial s_v}\right)}_{<0} + \frac{1-\alpha}{\rho}\underbrace{\left(\frac{\partial g}{\partial s_v}\right)}_{<0} + \frac{\phi}{\ell^h}\underbrace{\left(\frac{\partial \ell^h}{\partial s_v}\right)}_{>0}. \tag{22}$$

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, which leads 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,

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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 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) will increase the welfare of both countries.*

Proof. See Appendix. ■

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*

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

Proof. See Appendix. ■

In the proof of Lemma 5, we also compare (19) and (23) and find that a low value of ρ/φ is a sufficient condition for $\hat{H}_r > H_r$ (i.e., R&D underinvestment), in which case the wealth transfer that stimulates innovation could lead to Pareto improvement. The intuition behind this result can be understood in relation to the analysis in Grossman and Helpman (1991b). As in the original Grossman–Helpman model, when ρ decreases or φ increases, the positive externalities (i.e., the consumer-surplus and intertemporal-spillover effects) of R&D become more likely to dominate the negative externality (i.e., the business-stealing effect) of R&D. Therefore, R&D underinvestment is more likely to occur at a low value of ρ/φ.

5. DISCUSSION

In this section, we discuss a number of issues related to the theoretical framework. To derive closed-form solutions, we have kept the model simple and tractable

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by assuming an exogenous trade pattern (i.e., the high-income country produces innovative goods whereas the low-income country produces homogeneous goods) and ruling out the possibility of shifting the production of innovative goods to the low-income country, for two reasons. First, most of the least developed aid-receiving countries lack the necessary human capital for adapting foreign technology. Second, this simplification allows the open-economy model with two countries to be viewed as a closed-economy model with two types of households, which supply different labor inputs. Consequently, the redistribution effects are readily comparable with those in the literature on inequality and innovation. Furthermore, 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 antipoverty aid to the least developed countries, which have limited capacity to engage in the kind of (i) imitative R&D analyzed in Grossman and Helpman (1991a), (ii) adaptive R&D for technology transfer analyzed in Dinopoulos and Segerstrom (2010), and (iii) innovative R&D analyzed in Grossman and Lai (2004).

A second issue to consider is that foreign aid usually takes the form of income transfer rather than wealth transfer. In the model, we consider a redistribution of wealth simply to make our study more in line with the literature on inequality and innovation. However, the one-time wealth transfer is equivalent to a permanent income transfer. To see this, suppose the high-income country transfers an amount of income T to the low-income country in each period, and this amount is financed by a lump-sum tax τ. Then it can be shown that leisure in the high-income country becomes[20]

$$\ell^h = \frac{\phi}{1+\phi}\left(1 + \frac{\rho s_v}{\varphi} - \tau\right). \tag{24}$$

Therefore, the transfer of income continues to have the desired effect of reducing leisure and increasing labor supply in the innovative country.

A third and related issue is about the distortionary effects of taxation. The preceding discussion assumes the presence of a lump-sum tax, which is rarely available. In the case of distortionary taxes, the result that an income transfer leads to an increase in labor supply may no longer hold. Indeed, we find that an income transfer financed by a tax on wage income would lead to a decrease in labor supply. Similarly, an income transfer financed by a tax on asset income would cause a labor reallocation from R&D to production because the higher interest rate reduces the market value of inventions. As for a consumption tax, it will leave the equilibrium allocations of leisure, production labor and R&D labor unchanged. Therefore, none of these tax instruments deliver the original result. To restore the result, we can consider a tax on production-labor income. In this case, an income transfer financed by the production labor–income tax would increase R&D labor and potentially improve country h's welfare at a sufficiently

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low discount rate or high R&D productivity.[21] Furthermore, it is not unrealistic for production-labor income and R&D-labor income to be subject to different tax rates because in reality, R&D is often carried out by entrepreneurs, whose income can be taxed differently. Therefore, if the income of production workers is subject to a higher tax rate, then more individuals would choose to become R&D entrepreneurs instead.

Finally, we have sidestepped the issue of scale effects by normalizing the supply of labor in the high-income country to unity.[22] In this case, the population size no longer appears in the equilibrium growth rate; instead, it is the supply of labor that affects growth. In other words, when R&D scientists and engineers devote more time to research, they will generate more innovation. We believe that this implication is intuitive and plausible.

6. CONCLUSION

In this study, we have analyzed the growth and welfare effects of a global wealth redistribution. Even focusing on the innovation effect in the donating country, this study suggests that international transfers can (i) increase growth, (ii) reduce global inequality, and (iii) possibly lead to a Pareto improvement. We should emphasize that whether a Pareto improvement would occur depends on a number of factors, such as the extent of R&D underinvestment in the market economy and the empirical wealth elasticity of labor supply. These issues remain as empirical questions. However, even if a Pareto improvement does not occur, this outcome would not invalidate the main result of this paper that there is an unexplored benefit (through elastic labor supply and innovation), which reduces the welfare cost for the developed countries to provide antipoverty aid. Therefore, critiques of antipoverty aid may want to take into account these benefits for the United States.

NOTES

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).

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 of this literature.

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

7. Shimomura (2007) also considers a dynamic North–South model and relates Pareto-improving foreign aid to indeterminacy.

8. See Bertola et al. (2006) for an excellent textbook treatment of this literature.

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

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10. See, for example, Chatterjee et al. (2003) and Chatterjee and Turnovsky (2007) for a growth-theoretic analysis of this issue.

11. See Easterly (2003) for a review of this literature.

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

13. The more general isoelastic utility function $U = \int_0^\infty e^{-\rho t}[(C_t \ell_t^\phi)^{1-\sigma}/(1-\sigma)]dt$ also features unitary elasticity of substitution between leisure and consumption. For simplicity, we focus on the more tractable log utility function.

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

15. 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 nondrastic.

16. This value will be derived in the proof of Lemma 4 in the Appendix.

17. In the proof of Lemma 4, we also derive the equilibrium allocations of other variables.

18. In Section 5, we will discuss the implications of alternative financing schemes.

19. The signs of these derivatives will be derived in the proof of Proposition 3.

20. In an unpublished Appendix (available upon request), we provide the derivation for this result.

21. In an unpublished Appendix (available upon request), we provide the derivation for this result.

22. See Jones (1999) for an excellent discussion of scale effects in R&D-based growth models.

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APPENDIX

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

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

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 homogeneous-goods share of global output yields

$$W_t^l = [\phi(1-s_c)+\alpha] P_t C_t, \tag{A.2}$$

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 it with respect to time yields

$$\frac{\dot{\Omega}_t}{\Omega_t} = \frac{\dot{P}_t}{P_t} + \frac{\dot{C}_t}{C_t} - \frac{\dot{V}_t}{V_t}. \tag{A.3}$$

Substituting (4), (11), (A.1), and (A.2) into (A.3) yields (12). ■

Proof of Lemma 2. The profit share of global 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

$$\Omega_t \equiv \frac{P_t C_t}{V_t} = \frac{1}{1-\alpha}\left(\frac{z}{z-1}\right)(\rho + \lambda_t). \tag{A.4}$$

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

$$\frac{\dot{s}_{v,t}}{s_{v,t}} = \frac{\dot{V}_t^h}{V_t^h} - \frac{\dot{V}_t}{V_t} = \frac{W_t^h - (1+\phi) P_t C_t^h}{V_t^h} - \frac{W_t^h + W_t^l - (1+\phi) P_t C_t}{V_t}, \tag{A.5}$$

where the second equality uses (2), (3), and (A1). Substituting (11) and (A.2) into (A.5) and performing a few steps of mathematical manipulation yields

$$\dot{s}_{v,t} = \left[(1+\phi s_c - \alpha)\frac{P_t C_t}{V_t} - \varphi\right] s_{v,t} - \left[(1+\phi) s_c \frac{P_t C_t}{V_t} - \varphi\right]. \tag{A.6}$$

Substituting $\Omega_t \equiv P_t C_t / V_t$ into (A.6) 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 $\dot{V}_t = \dot{V}_t^h = \dot{V}_t^l = 0$. Imposing these conditions, (4), and (11) on (2) yields

$$P_t C_t^h = \left[\rho s_v + \varphi\left(1 - \ell_t^h\right)\right] V_t, \tag{A.7}$$

$$P_t C_t^l = \left[\rho(1-s_v) + \varphi\left(1-\ell_t^l\right)\omega_t\right] V_t, \tag{A.8}$$

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where $\omega_t \equiv W_t^l / W_t^h = W_t^l$ is the relative wage (to be determined below). Substituting (11), (A.7), and (A.8) into (3) yields

$$\ell_t^h = \frac{\phi}{1+\phi}\left(1 + \frac{\rho s_v}{\varphi}\right), \tag{A.9}$$

$$\ell_t^l = \frac{\phi}{1+\phi}\left[1 + \frac{\rho(1-s_v)}{\varphi \omega_t}\right]. \tag{A.10}$$

Country h's production-labor share of global output is $W_t^h H_{x,t} = (1-\alpha) P_t C_t / z$, and the profit share of global 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

$$(z-1) H_{x,t} = H_{r,t} + \rho/\varphi. \tag{A.11}$$

Combining (A.9), (A11), and $H_{x,t} + H_{r,t} = 1 - \ell_t^h$ yields

$$H_{r,t} = \frac{1}{z}\left[\frac{z-1}{1+\phi}\left(1 - \phi\frac{\rho s_v}{\varphi}\right) - \frac{\rho}{\varphi}\right], \tag{A.12}$$

$$H_{x,t} = \frac{1}{z}\left[\frac{1}{1+\phi}\left(1 - \phi\frac{\rho s_v}{\varphi}\right) + \frac{\rho}{\varphi}\right]. \tag{A.13}$$

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

$$\omega_t = \frac{z\alpha}{1-\alpha}\left(\frac{H_{x,t}}{L_t}\right) = \frac{1}{1-\alpha}\left[\alpha\left(1 + \frac{\rho}{\varphi}\right) + \phi\frac{\rho(1-s_v)}{\varphi}\right], \tag{A.14}$$

where the last equality is obtained by using $L_t = 1 - \ell_t^l$, (A.10), and (A.13). Finally, combining (13), (17), and $\dot{s}_{v,t} = 0$ yields

$$s_c = \frac{(1-\alpha)(\rho s_v + \varphi)}{(1+\phi)(\rho+\varphi) - \phi(\rho s_v + \varphi)}. \tag{A.15}$$

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

Proof of Proposition 3. Using (A.15), we can show that

$$\frac{\partial \ln s_c}{\partial s_v} = \frac{\rho}{\rho s_v + \varphi} + \frac{\phi\rho}{(1+\phi)(\rho+\varphi) - \phi(\rho s_v + \varphi)} > 0. \tag{A.16}$$

Also, $\partial \ln s_c / \partial s_v$ approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Using (A.13), we can show that

$$(1-\alpha)\frac{\partial \ln H_x}{\partial s_v} = -\left[\frac{\phi}{1+\phi}\frac{\rho(1-\alpha)}{\varphi}\right] \Big/ \left[\frac{1}{1+\phi}\left(1 - \phi\frac{\rho s_v}{\varphi}\right) + \frac{\rho}{\varphi}\right] < 0. \tag{A.17}$$

Note that Condition R implies that $1 - \phi\rho s_v/\varphi > 0$. Also, $\partial \ln H_x / \partial s_v$ approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Using (A.12), we can show that

$$\left(\frac{1-\alpha}{\rho}\right)\frac{\partial g}{\partial s_v} = (1-\alpha)\left(\frac{\varphi \ln z}{\rho}\right)\frac{\partial H_r}{\partial s_v} = -(1-\alpha)\left(\frac{\phi}{1+\phi}\right)\left(\frac{z-1}{z}\right)\ln z < 0, \tag{A.18}$$

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which is independent of ρ and φ. Using (A.9), we can show that

$$\phi \frac{\partial \ln \ell^h}{\partial s_v} = \phi \left(\frac{\rho}{\varphi + \rho s_v} \right) > 0, \tag{A.19}$$

which approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Using (A.10) and $L = 1 - \ell^l$, we can show that

$$\alpha \frac{\partial \ln L}{\partial s_v} = \frac{\alpha \rho \phi}{\omega \varphi - \rho \phi (1 - s_v)} \left[1 + \left(\frac{1 - s_v}{\omega} \right) \frac{\partial \omega}{\partial s_v} \right]. \tag{A.20}$$

As for $\partial \omega / \partial s_v$, we can use (A.14) to show that

$$\frac{\partial \omega}{\partial s_v} = -\frac{1}{1 - \alpha} \left(\frac{\rho \phi}{\varphi} \right) < 0. \tag{A.21}$$

Substituting (A.14) and (A.21) into (A.20) shows that $\partial \ln L / \partial s_v$ is positive and approaches zero as $\rho \to 0$ or $\varphi \to \infty$. Therefore, if ρ is sufficiently small or φ is sufficiently large, then the growth effect of wealth redistribution dominates the other effects, so that country h benefits from transferring some wealth to country l. As for country l's welfare,

$$\rho \frac{\partial U^l}{\partial s_v} = \underbrace{-\frac{1}{1 - s_c} \left(\frac{\partial s_c}{\partial s_v} \right)}_{<0} + \underbrace{\frac{\alpha}{L} \left(\frac{\partial L}{\partial s_v} \right)}_{>0} + \underbrace{\frac{1 - \alpha}{H_x} \left(\frac{\partial H_x}{\partial s_v} \right)}_{<0} + \underbrace{\frac{1 - \alpha}{\rho} \left(\frac{\partial g}{\partial s_v} \right)}_{<0} + \underbrace{\frac{\phi}{\ell^l} \left(\frac{\partial \ell^l}{\partial s_v} \right)}_{<0}. \tag{A.22}$$

Comparing (22) and (A.22) 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

$$\begin{aligned} &\rho(\theta U^h + (1 - \theta) U^l) \\ &\quad = \theta \ln C_0^h + (1 - \theta) \ln C_0^l + \left(\frac{1 - \alpha}{\rho} \right) g + \theta \phi \ln \ell^h + (1 - \theta) \phi \ln \ell^l \end{aligned} \tag{A.23}$$

subject to (i) $C_0^h + C_0^l = C_0 = (Z_0 H_x)^{1-\alpha} (L)^{\alpha}$, (ii) $g = (\varphi \ln z) H_r$, (iii) $H_x + H_r = 1 - \ell^h$, and (iv) $L = 1 - \ell^l$. 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

$$\frac{\partial \Gamma}{\partial C_0^h} = \frac{\theta}{C_0^h} - \mu = 0, \tag{A.24}$$

$$\frac{\partial \Gamma}{\partial C_0^l} = \frac{1 - \theta}{C_0^l} - \mu = 0, \tag{A.25}$$

$$\frac{\partial \Gamma}{\partial \ell^h} = -(1 - \alpha) \left(\frac{\varphi \ln z}{\rho} \right) + \theta \left(\frac{\phi}{\ell^h} \right) = 0, \tag{A.26}$$

$$\frac{\partial \Gamma}{\partial \ell^l} = (1 - \theta) \left(\frac{\phi}{\ell^l} \right) - \mu \alpha \left(\frac{C_0}{1 - \ell^l} \right) = 0, \tag{A.27}$$

$$\frac{\partial \Gamma}{\partial H_x} = -(1 - \alpha) \left(\frac{\varphi \ln z}{\rho} \right) + \mu (1 - \alpha) \left(\frac{C_0}{H_x} \right) = 0. \tag{A.28}$$

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Equations (A.24) and (A.25) imply that $\mu = 1/C_0$. Combining this condition with $H_x + H_r = 1 - \ell^h$, (A.26), and (A.28) yields (23). Comparing (19) and (23) yields

$$\hat{H}_r > H_r \Longleftrightarrow \underbrace{\left[1 - \left(\frac{1}{1+\phi}\right)\frac{z-1}{z}\right]}_{A>0} > \underbrace{\left[\theta\left(\frac{\phi}{1-\alpha}\right)\frac{1}{\ln z} + \frac{z - \ln z}{z \ln z} - \frac{\phi}{1+\phi}\left(\frac{z-1}{z}\right)s_v\right]}_{B}\frac{\rho}{\varphi}. \quad \textbf{(A.29)}$$

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

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