Capital Intensity, Neutral Technological Change, and Earnings Inequality

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Abstract

The paper furthers the neoclassical theory of earnings inequality. The inequality multiplier is derived as the amount by which inequality in skills must be multiplied to yield earnings inequality. Neutral technological change and the real interest rate affect inequality by changing capital per worker. The effect of capital per worker on the inequality multiplier is related to skill differentials and capital-skill complementarity. The results explain increasing inequality from the mid 1970's into the 1990's.

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1. Introduction

This paper furthers the neoclassical theory of earnings inequality. Under certain conditions identified in this paper, an increase in capital per worker raises earnings inequality as measured by the coefficient of variation. Neutral technological change, by inducing capital accumulation, can then raise earnings inequality.

Increases in earnings and income inequality from the 1970's onward have been extensively analyzed in the literature.[1] Two major explanations for the increases are skill-biased technological change and international trade that increases the relative demand for more skilled workers.[2] Data indicative of the increases in inequality are shown in Table 1.[3] The Gini Coefficient is a standard measure of inequality that is less sensitive to lower earnings than the variance of logarithms and less sensitive to higher earnings than the measure used in this paper, the coefficient of variation. The next two columns show capital equipment per worker and capital structures per worker. The skill column is the proportion of labor with four years of college or more. The sixth column shows multifactor productivity. The real interest rate in the last column is measured by the interest rate on long term treasury bonds minus the rate of inflation. Inequality, productivity and the real interest rate increased more rapidly from about 1980 on, while capital equipment per worker grew at a greater rate from 1975 on and skill grew steadily over the entire period.

In an approach that is also based on a neoclassical production function, Per

[1]See Lawrence F. Katz and David H. Autor (1999) and P. Gottschalk and T.M. Smeeding (2000) for surveys of the empirical evidence. A.B. Atkinson and F. Bourguignon (2000) and Sattinger (2001) provide general surveys of income distribution. Linda Wong (2003) examines wage inequality in the context of a matching model.

[2]Daron Acemoglu (2002), Eli Berman, John Bound and Stephen Machin (1998), Katz and Autor (1999, p. 1530-1535) and Chinhui Juhn, Kevin Murphy and Brooks Pierce (1993) discuss skill-biased technological change. Adrian Wood (1995) considers the effect of trade.

[3]The Gini Coefficient is based on individual earnings from the March Current Population Survey for full-time, year-round workers of both sexes. Capital equipment per worker is nonresidential equipment and software measured as a chain-type quantity index by the Bureau of Economic Analysis divided by total nonfarm employment, from the Bureau of Labor Statistics. Capital structure per worker is nonresidential structures divided by total nonfarm employment. The skill measure is the proportion of hours worked by men and women with four years of college, from the Digest of Educational Statistics, weighted by male and female employment. Productivity is measured by the Major Sector Multifactor Productivity Index for manufacturing. The real interest rate is measured by the average interest rate on U.S. Treasury bonds with maturity over ten years minus inflation as measured by increases in the yearly average Consumer Price Index (CPI-U).

Krusell, Lee E. Ohanian, José-Victor Rios-Rull, and Giovanni L. Violante (2000; see also Ohanian et al, 2000) relate changes in the ratio of skilled to unskilled wage rates to capital-skill complementarity (Zvi Griliches, 1969; see also Sattinger, 1980, Chapter 4). The production function used is

$$k_{st}^{\alpha}\left(\mu u_t^{\eta} + (1-\mu)(\lambda k_{et}^{\nu} + (1-\lambda)s_t^{\nu})^{\eta/\nu}\right)^{(1-\alpha)/\eta} \qquad (1.1)$$

where the subscript t indicates time, k_{st} is structure capital, k_{et} is equipment capital, u_t is unskilled labor and s_t is skilled labor. This is a nested Constant Elasticity of Substitution production function in the three variables k_{et}, u_t and s_t. A unit of labor is skilled if the worker has a college degree. Capital-skill complementarity holds if $\eta > \nu$. With this condition, a higher rate of growth of equipment capital yields a greater skill premium. The authors find that changes in factor quantities explain most of the skill premium variations in the past three decades. Both Krusell et al and this paper conclude that changes in factor quantities (specifically the ratio of capital to workers) affect the skill premium (or differential). This paper uses a simpler technology, extends the results to heterogeneous workers and earnings inequality, and considers how real interest rates and neutral technological change affect the amount of capital per worker.

In the neoclassical theory relating real interest rates to inequality (Section 2), aggregate human capital or skill enters an aggregate production function.[4] A worker's marginal product is then linearly related to the worker's human capital or skill level. Using this linear relation, inequality in earnings can be related to inequality in human capital or skill. The inequality multiplier is the factor by which skill inequality is multiplied to yield earnings inequality, as measured by the coefficient of variation. The inequality multiplier is derived analytically in Section 3. Section 4 considers conditions under which an increase in capital intensity raises the inequality multiplier, using the neoclassical condition that factor prices equal marginal products. Theorem 4.3 shows that if output per worker is homogeneous of degree less than one in capital per worker and human capital per worker, and if the elasticity of substitution between the two variables is less than one, then capital intensity raises the inequality multiplier. Section 5 analyzes determinants of capital intensity. Neutral technological change is shown to induce capital accumulation, generating greater inequality if the conditions in

[4] An extensive literature disputes the use of production functions with substitutable factors and aggregated capital. Standard references are C.J. Bliss, 1975; Edwin Burmeister, 1980; and G.C. Harcourt, 1969.

Section 4 hold. Section 6 considers empirical evidence from growth accounting and factor shares on the parameters of the production function. Section 7 considers effects of the real interest rate on the distribution of skill and net effects of variables on inequality.

2. Production with Heterogeneous Workers

2.1. The Production Function

Assume there are n employed workers in an economy. Let g_i be the skill of worker i, $i = 1, n$. This skill could take the form of human capital or productive ability. Let

$$G = \sum_{i=1}^{n} g_i \tag{2.1}$$

be the aggregate skill in the economy. Let K be the aggregate amount of capital in the economy. Suppose aggregate production in the economy is given by $Q = F(n, K, G)$. Assume $F(n, K, G)$ has constant returns to scale in n, K and G. Let $\kappa = K/n$ be capital per worker and let $\gamma = G/n$ be average skill or human capital per worker. Then output per worker can be written as

$$f(\kappa, \gamma) = F(n, K, G)/n = F(1, K/n, G/n) = F(1, \kappa, \gamma) \tag{2.2}$$

Let $f_1 = \partial f/\partial\kappa$ and $f_2 = \partial f/\partial\gamma$. In terms of κ and γ, aggregate output can be written as

$$Q = nf(\kappa, \gamma) \tag{2.3}$$

Although $F(n, K, G)$ has constant returns to scale in n, K and G, there is no requirement that $f(\kappa, \gamma)$ have constant returns to scale in κ and γ. If n, K and G all double, κ and γ stay the same so that $nf(\kappa, \gamma)$ doubles, whether or not $f(\kappa, \gamma)$ has constant returns to scale in κ and γ.

2.2. Worker Marginal Products

Theorem 2.1. *As n increases, the marginal product for worker i approaches*

$$MP_i = f(\kappa, \gamma) - f_1\kappa + f_2(g_i - \gamma) \tag{2.4}$$

Proof. The marginal product of a worker with skill g_i can be calculated as the difference in output with and without the worker. Without the worker, there are

$n-1$ workers, capital per worker is $K/(n-1)$, and average skill is $(G-g_i)/(n-1)$. Then the changes in n, κ and γ are

$$\triangle n = 1 \tag{2.5}$$

$$\triangle \kappa = \frac{K}{n} - \frac{K}{n-1} = -\frac{K}{n(n-1)} = -\frac{\kappa}{n-1} \tag{2.6}$$

$$\triangle \gamma = \frac{G}{n} - \frac{G-g_i}{n-1} = -\frac{G}{n(n-1)} + \frac{g_i}{n-1} = \frac{g_i-\gamma}{n-1} \tag{2.7}$$

For n sufficiently large the changes approach $\triangle\kappa = -\kappa/n$ and $\triangle\gamma = (g_i - \gamma)/n$. Then the marginal product of worker i, calculated as the total differential of Q, is

$$MP_i = f(\kappa,\gamma)\triangle n + nf_1\triangle\kappa + nf_2\triangle\gamma = f(\kappa,\gamma) - f_1\kappa + f_2(g_i - \gamma) \tag{2.8}$$

completing the proof.

Worker i's marginal product consists of three terms. The first term, $f(\kappa,\gamma)$, is output per worker. The second term, $-f_1\kappa$, arises because an additional worker reduces the capital available to other workers. That is, the capital used by a worker has an opportunity cost determined by the capital's contribution to production for the remaining workers. The third term, $f_2(g_i - \gamma)$, arises because worker i raises or lowers the average skill level. The average of $g_i - \gamma$ over all workers is zero, so that the average marginal product for all workers is $f(\kappa,\gamma) - f_1\kappa$. Because of the construction of the marginal product as the total differential of output, a worker's marginal product is a linear function of g_i independent of the functional form of output per worker, $f(\kappa,\gamma)$.

3. Inequality Multiplier

This section relates inequality in earnings to inequality in worker skills. The two inequality levels will not necessarily be the same since marginal products will not in general be proportional to skills. The economic system exaggerates or moderates skill differences in generating the distribution of earnings, depending on the functional form of output per worker and levels of average skill and capital per worker.

Marginal products are related to earnings through the neoclassical assumption. Specifically, assume that factor prices equal factor marginal products in equilibrium. Then the wage rate for worker i is MP_i. If r is the rental cost of capital, then $r = \partial F/\partial K = n\partial f(K/n, \gamma) = nf_1(1/n) = f_1$. Let Γ be the standard deviation of skills. Since the average wage is $f(\kappa,\gamma) - f_1\kappa$, the standard deviation of wages is

$$\sqrt{\left(\sum_{i=1}^{n}(MP_i - (f(\kappa,\gamma) - f_1\kappa))^2\right)/n} = \sqrt{\left(\sum_{i=1}^{n}(f_2(g_i - \gamma))^2\right)/n} = f_2\Gamma \tag{3.1}$$

A descriptive measure of inequality is the coefficient of variation, the standard deviation divided by the mean. Assuming all workers supply the same amount of labor, the coefficient of variation of earnings, ω, is given by the standard deviation of wages in 3.1 divided by the average wage:

$$\omega = \frac{f_2\Gamma}{f(\kappa,\gamma) - f_1\kappa} = \frac{f_2\gamma}{f(\kappa,\gamma) - f_1\kappa}\frac{\Gamma}{\gamma} \tag{3.2}$$

In this expression, Γ/γ is the coefficient of variation of skills.

Definition 3.1. *The inequality multiplier is defined as*

$$\pi = \frac{f_2\gamma}{f(\kappa,\gamma) - f_1\kappa} \tag{3.3}$$

With this definition, earnings inequality ω equals the inequality multiplier times inequality in skills, as measured by the coefficient of variation: $\omega = \pi(\Gamma/\gamma)$.

4. Effects of Capital per Worker

4.1. The Inequality Multiplier

Definition 4.1. *The capital-inequality hypothesis holds if an increase in capital per worker raises the inequality multiplier.*

Theorem 4.2. *Suppose aggregate output is given by $Q = nf(\kappa,\gamma)$ in 2.3 and suppose $f_{11} < 0$.The capital-inequality hypothesis holds if and only if*

$$\pi < -\frac{f_{12}\gamma}{f_{11}\kappa} \tag{4.1}$$

Proof. Differentiating π in 3.3 with respect to κ yields

$$\frac{\partial \pi}{\partial \kappa} = \frac{f_{12}\gamma}{f(\kappa,\gamma) - f_1\kappa} - \frac{\pi}{f(\kappa,\gamma) - f_1\kappa}\left(f_1 - f_1 - \kappa f_{11}\right) = \frac{f_{11}\kappa}{f(\kappa,\gamma) - f_1\kappa}\left(\pi + \frac{f_{12}\gamma}{f_{11}\kappa}\right) \tag{4.2}$$

Since $f_{11} < 0$, $\partial\pi/\partial\kappa > 0$ if and only if

$$\pi + \frac{f_{12}\gamma}{f_{11}\kappa} < 0 \tag{4.3}$$

Rearranging yields 4.1, completing the proof.

Further conditions can be derived assuming a specific functional form for output per worker:

$$f(\kappa,\gamma) = \left(\delta\kappa^{\rho} + (1-\delta)\gamma^{\rho}\right)^{\epsilon/\rho}, \quad \rho < 1, \rho \neq 0, 0 < \delta < 1, \epsilon > 0 \tag{4.4}$$

This function is homogeneous of degree ϵ and has constant elasticity of substitution $\sigma = 1/(1-\rho)$ (Ferguson, 1969, pp. 90-92). If $\rho > 0$ then $\sigma > 1$, and if $\rho < 0$ then $\sigma < 1$.

Theorem 4.3. *Suppose $f(\kappa,\gamma)$ is given by 4.4. Then*

$$\pi = \frac{(1-\delta)\epsilon\gamma^{\rho}}{\delta(1-\epsilon)\kappa^{\rho} + (1-\delta)\gamma^{\rho}} \tag{4.5}$$

If $\rho < 0$ and $\epsilon < 1$ or if $\rho > 0$ and $\epsilon > 1$, then $\partial\pi/\partial\kappa > 0$ and the capital-inequality hypothesis holds.

Proof. Since $f(\kappa,\gamma)$ is homogeneous of degree ϵ, $\epsilon f(\kappa,\gamma) = f_1\kappa + f_2\gamma$ by Euler's Theorem. Using this expression to solve for $f_1\kappa$ and then substituting into 3.3 yields 4.5. Differentiation of 4.5 with respect to κ yields

$$\frac{\partial \pi}{\partial \kappa} = \frac{(\epsilon - 1)\rho\epsilon\delta(1-\delta)\kappa^{\rho-1}\gamma^{\rho}}{\left(\delta(1-\epsilon)\kappa^{\rho} + (1-\delta)\gamma^{\rho}\right)^2} \tag{4.6}$$

Then $\partial\pi/\partial\kappa > 0$ if $(\epsilon-1)\rho > 0$. The two cases in the theorem then yield $\partial\pi/\partial\kappa > 0$ and the capital-inequality hypothesis, completing the proof.

When $\rho = 0$, the elasticity of substitution is 1 and $f(\kappa,\gamma)$ takes a Cobb-Douglas form. If $f(\kappa,\gamma)$ takes the Cobb-Douglas form $A\kappa^{\alpha}\gamma^{\beta}$, then $\pi = \beta/(1-\alpha)$, a constant unaffected by κ or r. If in addition $\alpha + \beta = 1$, then $\pi = 1$. The inequality multiplier and the capital-inequality hypothesis can be analyzed using other functional forms, such as Sato's almost homogeneous function (R. Sato, 1977, p. 564).

4.2. Skill Differentials

Consider two workers with $g_1 > g_2$. The skill differential between the workers is the ratio of their wages. Assuming wages equal marginal products, the skill differential is

$$\theta = \frac{f(\kappa,\gamma) - f_1\kappa + f_2(g_1-\gamma)}{f(\kappa,\gamma) - f_1\kappa + f_2(g_2-\gamma)} \tag{4.7}$$

Then

$$\frac{\partial\theta}{\partial\kappa} = \frac{(g_1-g_2)(f(\kappa,\gamma)-f_1\kappa)\kappa f_{11}}{\gamma\left(f(\kappa,\gamma)-f_1\kappa+f_2(g_2-\gamma)\right)^2}\left(\pi + \frac{f_{12}\gamma}{f_{11}\kappa}\right) \tag{4.8}$$

Comparison with Theorem 4.2 shows that $\partial\theta/\partial\kappa > 0$ under the same conditions that $\partial\pi/\partial\kappa > 0$.

4.3. Capital-Skill Complementarity

The capital-inequality hypothesis can be related to capital-skill complementarity as developed by Griliches (1969). Let σ_{ij} be the Allen-Uzawa partial elasticity of substitution between factor i and factor j. These elasticities are used to calculate the effects of factor prices on quantities demanded of factors. With the functional form in 4.4, it can be shown that $\sigma_{Kn} = \sigma_{Gn} = 1$ and

$$\sigma_{KG} = 1 + \frac{\rho/\epsilon}{1-\rho} \tag{4.9}$$

Capital-skill complementarity arises if $\sigma_{KG} < \sigma_{Kn}$. From 4.9, this arises if $\rho < 0$ or equivalently if $\sigma = 1/(1-\rho) < 1$. Thus the capital-inequality hypothesis is not equivalent to capital-skill complementarity unless $\epsilon < 1$.

5. Determinants of Capital per Worker

5.1. Neutral Technological Change

Technological change can be introduced by writing output as $Q = F(n, K, G)A$, where A is a measure of productivity. Increases in A reflect Hicks neutral technological change (John Hicks, 1932). Then output per worker is given by $f(\kappa,\gamma)A = F(1,\kappa,\gamma)A$. The technology parameter A drops out of the inequality multiplier, so previous results remain valid. Although A does not affect the inequality multiplier directly, it induces capital accumulation which then affects the inequality multiplier.

Theorem 5.1. *Assume $f_{11} < 0$ and r, γ and Γ are given. If the capital-inequality hypothesis holds and capital adjusts optimally, Hicks neutral technological change raises the inequality multiplier and earnings inequality.*

Proof. The first order condition for the optimal capital stock is

$$r = \frac{\partial Q}{\partial K} = \frac{\partial nF(1, K/n, G/n)A}{\partial K} = \frac{\partial f(\kappa,\gamma)}{\partial \kappa}A = f_1 A \tag{5.1}$$

Assuming r and γ are exogenously determined, implicit differentiation of $r = f_1 A$ yields

$$0 = f_{11}\frac{d\kappa}{dA} + f_1 \tag{5.2}$$

or

$$\frac{d\kappa}{dA} = -\frac{f_1}{f_{11}} > 0 \tag{5.3}$$

Then an increase in A raises κ. Assuming the capital-inequality hypothesis holds, the increase in κ raises the inequality multiplier and earnings inequality in 3.2, completing the proof.

As a result of this theorem, whether technological change is skill-biased cannot be inferred solely from increases in the skill differential.

5.2. Real Interest Rate

Theorem 5.2. *Assume $f_{11} < 0$ and A, γ and Γ are given. If the capital-inequality hypothesis holds, an increase in the interest rate reduces the inequality multiplier and earnings inequality.*

Proof. From the first order condition in 5.1, implicit differentiation yields

$$1 = f_{11}\frac{\partial \kappa}{\partial r}A \tag{5.4}$$

or

$$\frac{\partial \kappa}{\partial r} = \frac{1}{f_{11}A} < 0 \tag{5.5}$$

Then by the capital-inequality hypothesis, an increase in r reduces π and earnings inequality, completing the proof.

Note that an increase in r may raise inequality in income from all sources, since interest income is received disproportionately by higher income individuals.

6. Empirical Evidence

6.1. Growth Accounting

Let ϵ_κ and ϵ_γ be the elasticities of output per worker with respect to κ and γ, respectively. The parameter ϵ in 4.4 is then the sum of these output elasticities (Ferguson, 1969, p. 83). Results from the growth accounting literature provide evidence on the values of ϵ_κ and ϵ_γ. N. Gregory Mankiw, David Romer and David N. Weil (1992) estimate an augmented Solow model using the following functional form:

$$Y = K^\alpha H^\beta (AL)^{1-\alpha-\beta} \tag{6.1}$$

where K is physical capital, H is human capital and AL is effective units of labor. Then output per effective unit of labor is

$$\frac{Y}{AL} = \left(\frac{K}{AL}\right)^\alpha \left(\frac{H}{AL}\right)^\beta \tag{6.2}$$

so that $\epsilon_\kappa = \alpha$ and $\epsilon_\gamma = \beta$. They use data collected by Robert Summers and Alan Heston (1988) and enrollment data as a proxy for the human capital savings rate. With observations on 98 countries for which oil production is not the dominant industry, Mankiw, Romer and Weil obtain results implying $\alpha = .31$ and $\beta = .28$ (1992, p. 420). Then $\epsilon = .31 + .28 = .59 < 1$. Assuming their estimates of ϵ_κ and ϵ_γ are robust to the functional form used in the estimation, the results would be accurate for the functional form assumed in Theorem 4.3.

Jess Benhabib and Mark M. Spiegel (1994) use a later set of data from Summers and Heston (1991), combined with estimated human capital stocks developed by George Kyriacou (1991). Using a limited sample of countries for which physical capital stocks were available, they obtain

$$Log(Y) = 3.391 + .614 Log(K) + .349 Log(L) + .189(H) + error \tag{6.3}$$

where L is labor. This Cobb-Douglas form has increasing returns to scale since .614+.349+.189=1.152>1. It implies that $\epsilon_\kappa = .614$ and $\epsilon_\gamma = .189$ so that $\epsilon = .803 < 1$.[5]

Kreuger and Lindahl (2001) replicate and extend the Benhabib and Spiegel results using the annualized change in $Log(GDP)$, 1965-1985, as the dependent variable. With a term for the level of schooling in 1965 included, the coefficient of the change in the logarithm of schooling is .178 and the coefficient of the change in the logarithm of physical capital is .461 (Kreuger and Lindahl, 2001, p. 1112). These results imply $\epsilon_\kappa = .461$ and $\epsilon_\gamma = .178$, so that $\epsilon < 1$.

The results from growth accounting support the conclusion that $\epsilon = \epsilon_\kappa + \epsilon_\gamma < 1$. If in addition $f(\kappa, \gamma)$ takes the CES functional form in 4.4 and $\rho < 0$, the capital-inequality hypothesis holds by Theorem 4.3. However, the growth accounting literature provides no evidence on the elasticity of substitution between physical capital per worker and human capital per worker.

6.2. Factor Shares

By Theorem 4.3, if $\epsilon < 1$, the capital-inequality hypothesis holds if $\rho < 0$. Then $\sigma = 1/(1-\rho) < 1$. This value of the elasticity of substitution has consequences for factor shares that could be used to test whether conditions for the capital-inequality hypothesis hold. Using the neoclassical assumption that $r = f_1$, capital's share of income is given by

$$\frac{rK}{Q} = \frac{rn\kappa}{nf(\kappa, \gamma)} = \frac{r\kappa}{f(\kappa, \gamma)} = \frac{f_1\kappa}{f(\kappa, \gamma)} \tag{6.4}$$

Theorem 6.1. *Suppose output per worker is given by 4.4. An increase in γ raises capital's share of income if and only if $\sigma < 1$.*

Proof. Differentiating capital's share in 6.4 with respect to γ yields

$$-\frac{\epsilon\rho\delta(1-\delta)\kappa^\rho\gamma^{\rho-1}}{(\delta\kappa^\rho + (1-\delta)\gamma^\rho)^2} \tag{6.5}$$

[5] The coefficient of $Log(H)$ is not significant. Benhabib and Spiegel provide other estimates showing the human capital variable enters negatively or insignificantly.

This derivative is positive whenever $\rho < 0$, which holds whenever $\sigma < 1$, completing the proof.

With output per worker given by 4.4, income from output can be divided between capital and labor shares. Labor's share of income, given by one minus capital's share in 6.4, combines a return to raw labor with a return to skill or human capital. If an increase in γ reduces capital's share, then it raises labor's share.

The measurement of labor and capital shares is complicated by the need to allocate proprietor's income and retiree payments between the two categories (Kreuger, 1999). Although the current literature provides no evidence regarding the effects of human capital on factor shares, the implications of $\sigma < 1$ provide an indirect means of testing for conditions for the capital-inequality hypothesis.[6]

7. Conclusions

7.1. Distribution of Skills

Following the framework of some human capital models, the distribution of skills is regarded as endogenously determined, whereas the analysis in this paper has treated γ and Γ as given. The distribution of skills could be affected by both the real interest rate and technological change. The interest rate could affect the distribution of skills through two routes. First, a change in the interest rate could alter the level of capital per worker, affecting marginal products and wages at different skill or human capital levels. The changes in wage rates could then lead workers to change levels of investment in human capital and the resulting distribution of skills or human capital. In the second route, changes in the interest rate can directly affect decisions to invest in human capital in the same way that the interest rate affects investments in physical capital. At higher interest rates, workers would undertake fewer human capital investments, everything else the same. For example, James Heckman, Lance Lochner and Christopher Taber (1998) develop a general equilibrium model with heterogeneous agents to examine wage differentials. The interest rate (and discount rates for individuals) explicitly enter the analysis. However, the interest rate is assumed fixed at .05 (1998, p. 19) and effects of changes in the interest rate are not derived.

[6] Using the functional form in 1.1, Krusell et al (2000a, p. 1041) estimate that the elasticity of substitution between skilled labor and capital equipment, s_t and k_{et}, is .67. However, this is not an Allen-Uzawa partial elasticity of substitution.

Neutral technological change can indirectly affect decisions to invest in human capital. Even though A in Section 5.1 drops out of the inequality multiplier, an increase in A induces capital accumulation. If the capital-inequality hypothesis holds, the capital accumulation would then raise skill differentials, increasing the incentive to invest in human capital.

While some of the work on human capital investment decisions may carry implications of the real interest rate for aggregate and average human capital, there are no clear implications in this literature for the effects of the interest rate or technological change on the distribution of human capital or on Γ/γ. Because Γ/γ is affected mainly by new entrants and retirees, it would change slowly over time. It is then reasonable to treat Γ/γ as given for the purposes of the analysis in this paper.

7.2. Overall Implications

The overall implications of this paper's results for earnings inequality can now be considered. From 3.2, earnings inequality can be decomposed into the product of the inequality multiplier and skill inequality. The increases in capital per worker from 1975 on shown in Table 1 would have generated a higher inequality multiplier if the capital-inequality hypothesis holds. The technological change shown in Table 1 would have induced capital accumulation, while the increases in the real interest rate from 1981 on would have reduced it.[7] Increases in average skill would also have induced capital accumulation. The net effect is a substantial increase in capital equipment per worker from 1975 to 1999.[8] If the capital-inequality hypothesis holds, this net increase in capital per worker would raise earnings inequality. The primary cause would be technological change (not necessarily skill-biased), supplemented by increases in average skill and moderated by higher interest rates.

[7] Krusell et al (2000) observe that a price index for capital equipment developed by Robert J. Gordon (1990) declined at a 4.5 percent rate through 1975. They calculate that it declined at a 6 percent rate afterwards. These price declines would also contribute to capital accumulation. Their relation to technological change (perhaps skill-biased) is unclear, particularly since capital goods production is typically labor intensive.

[8] Krusell et al (2000, p. 1031) report that their measure of the stock of capital equipment grew at 6.2 percent per year from 1963 to 1975, and at 7.5 percent afterwards.

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Table 1: Inequality and Determinants

Year	Gini	Equipment	Structures	Skill	Productivity	Real Interest Rate
1967	0.340	0.476	0.809	0.098	77.5	1.753
1968	0.333	0.491	0.810	0.098	79.9	1.059
1969	0.326	0.506	0.808	0.107	80.5	0.617
1970	0.326	0.530	0.829	0.114	79.2	0.875
1971	0.328	0.550	0.849	0.115	81.4	1.340
1972	0.336	0.561	0.844	0.119	84.4	2.429
1973	0.330	0.580	0.836	0.129	85.9	0.101
1974	0.326	0.607	0.844	0.146	81.3	-4.018
1975	0.327	0.641	0.877	0.146	78.9	-2.116
1976	0.328	0.645	0.867	0.149	81.7	0.981
1977	0.332	0.655	0.852	0.151	82.9	0.557
1978	0.333	0.665	0.831	0.157	83.6	0.287
1979	0.335	0.687	0.828	0.165	82.7	-2.558
1980	0.331	0.716	0.850	0.171	81.3	-2.690
1981	0.334	0.740	0.873	0.183	81.9	2.588
1982	0.340	0.771	0.919	0.202	83.3	6.033
1983	0.340	0.783	0.932	0.206	85.2	7.642
1984	0.342	0.781	0.917	0.208	87.8	7.689
1985	0.348	0.789	0.920	0.211	89.2	7.152
1986	0.355	0.800	0.926	0.215	90.7	6.244
1987	0.353	0.798	0.924	0.218	93.5	5.034
1988	0.355	0.796	0.915	0.225	95.2	4.876
1989	0.362	0.801	0.912	0.228	93.4	3.788
1990	0.359	0.809	0.920	0.230	93.3	3.333
1991	0.355	0.833	0.945	0.230	92.4	3.959
1992	0.360	0.846	0.952	0.238	94.0	4.521
1993	0.389	0.856	0.945	0.239	94.9	3.455
1994	0.395	0.864	0.925	0.246	97.3	4.810
1995	0.388	0.883	0.914	0.247	99.2	4.135
1996	0.393	0.911	0.911	0.251	100.0	3.795
1997	0.394	0.941	0.906	0.256	103.5	4.368
1998	0.393	0.980	0.903	0.259	106.3	4.088
1999	0.399	1.019	0.902	0.264	109.4	3.933