Wage Inequality, Outsourcing, and Education

Chu Ping Lo* and K.C. Fung

National Taiwan University and University of California, Santa Cruz

Abstract We present a simple model to explain why wage inequality in the U.S. increased in the 1980s but decreased in the 1970s, in which we argue that educational investment might deteriorate wage inequality temporarily, but permanently decrease it. A country would not necessarily present the Kuznets inverted-U curve if having sufficient educational investment. Acceleration in the educational investment rate leads to an increasing supply of skilled labor and temporarily generates a higher technology growth rate, which might deteriorate the wage inequality in transition. In the new equilibrium, the wage inequality is permanently decreased because the relative supply of skilled labor increases to a higher level while technology returns to its balanced growth rate. However, the temporary acceleration in educational investment is at the expense of current consumption, which is not a tradeoff preferred by every nation.

Keywords: International outsourcing, wage inequality, educational investment

JEL Classification: F12, F15, F16

1. Introduction

In Feenstra and Hanson’s (1996) model, international outsourcing gives rise to a consequent concentration of production in more skilled labor-intensive activities in both countries, creating a rising demand for skilled labor and, therefore, a larger skill premium. Feenstra and Hanson’s (1996) model helps to explain why rising wage inequalities were observed in the late 1980s in both the United States and Mexico after Mexico liberalized its capital control in 1989. In an empirical study, Berman, Bound, and Griliches (1993) found that investment in computers accounted for approximately one-quarter to one-half of the move within industry away from production labor during the 1980s in the U.S. This implies that a combination of outsourcing trade and technology change can account for the majority shift in both wages and employment towards skilled labor, and the technology change has played a dominant role in this shift. However, the above model fails to explain why wage inequality increased in 1980s
in the U.S. but declined in the 1970s, as in Figure 1, while outsourcing trade increased steadily in both the 1970s and 1980s (Feenstra and Hanson, 1997).

Antràs, Garicano, and Ross-Hansberg (2006) have developed a theory of off-shoring in which agents with heterogeneous abilities sort themselves into international teams. They argue that globalization always increases the South’s wage inequality, but increases the North’s wage inequality only if the costs of knowledge communication within the international teams are relatively low. This is because the higher costs of knowledge communication deter the formation of international teams, reducing competition from low wage workers in the South, leading to lower wage inequality in the North. Antràs, Garicano, and Ross-Hansberg (2006) suggested that it was high knowledge communication costs and the consequent low trade integration which resulted in the low wage inequality in the U.S. in the 1970s compared to the 1980s. However, in their model, outsourcing always leads to a rising wage inequality in the South, which might not be in line with the experience observed in Mexico (i.e., the South): wage inequality was reduced in the United States in the 1970s, as it was in Mexico.2

In another thread of literature, educational investment plays a role in income redistribution. Gregoria and Lee (2002) examined a range of countries from 1960 to 1990 and found that higher educational attainment plays a significant role in making the income distribution more equal. They also found that educational inequality increases income inequality. In a cross-section of more than eighty economies, Clarke (1992) also found a strong and statistically significant negative correlation between basic education enrollment rates and the level of income inequality.

Therefore, in this paper, we introduce education into Romer’s (1990) model to demonstrate how the globalization-driven wage inequality can be mitigated by educational investment (especially basic and even pre-school education). We argue that, while a government equally distributes educational investments, the educational investment might temporarily deteriorate, but permanently decrease, wage inequality.

Hsieh and Woo (2005) applied Feenstra and Hanson’s (1996) model to examine the effect of China’s opening to foreign trade and investment on the labor market in Hong Kong. The share of U.S. trade with Mexico only accounted for some 8% of U.S. total trade during the 1990s. Considering Mexico’s small size relative to the U.S., the open policy of Mexico in the 1980s may not have had a substantial effect on the U.S. labor market. In contrast, there is an advantage to examining Hong Kong’s experiences with China, because the imported intermediate inputs from China exceeded 50% of Hong Kong’s total intermediate inputs in the early 1990s (see Hsieh and Woo 2005). In the late 1970s, China opened its economy to
foreign investors, leading to a large transfer of low-skilled jobs to China, and Hong Kong has been the largest source of foreign direct investment to China. People might expect Hong Kong to have experienced greater wage inequality than other economies such as the U.S.

However, in aggregate economy, the relative wage rate of Hong Kong’s skilled labor increased by less than 5% from 1986 to 1996, while the employment ratio of non-production workers to production workers almost tripled during that period. More than that, the relative wage rate of Hong Kong’s skilled labor was almost unchanged in the manufacturing sectors from 1986 to 1996. Why does international outsourcing create a massive relocation of employment but affect relative wage rates only slightly in the case of Hong Kong? Two other East Asian countries, South Korea (the Republic of Korea) and Taiwan, also had experiences similar to those of Hong Kong, with a modest wage gap in the non-agricultural sector since the 1960s.

Comparing to the U.S. and Hong Kong, it is feasible to refer to South Korea, Taiwan, and Mexico before the 1980s as the South; therefore, wage inequality in these countries should have had increased with international outsourcing trade and with skill-biased technological change, as suggested by the models of Feenstra and Hanson (1996), Ethier (2005), and Antràs, Garicano, and Ross-Hansberg (2006). Instead, while Mexico saw a widening wage inequality between skilled and unskilled labor in the late 1980s, so did Chile (Robbins, 1996), with wage inequality in South Korea and Taiwan leveling off, as shown in Figure 2. Note that Hummels, Ishii, and Yi (2001) have shown that Mexico did not experience more international outsourcing trade than these two East Asian countries from the 1970s to 1990s. It is also widely acknowledged that both Taiwan and South Korea have experienced substantially high growth rates in technology in comparison to Mexico.

Why the trends of wage inequality present a mixed picture between the Eastern Asian and Latin American countries? Obviously, we need more than outsourcing, biased technological change, and even knowledge communication costs for further explanation. We argue that education, especially basic and pre-school education, might be a solution. The logic is clear: the higher spending on education is, the greater the supply of skilled labor, which decreases wage inequality.

From 1965 to 1989, South Korea exceeded Mexico to a large extent in educational investment, especially in public expenditures per student on basic education. As shown in Table 1, both Mexico and South Korea began with the same rate of 0.5% for Primary/PGDP in 1965, but South Korea rose to 6.45% while Mexico only rose to 1.30% in 1989. A similar pattern is found in the level of secondary education. In contrast, wage inequality in South
Korea was reduced sharply with expansions in basic education during this period. Having consistently allocated more resources to education year by year in comparison to Mexico, South Korea becomes capable of providing relatively sufficient skilled labor, suppressing the wage inequality as a result. In contrast, Airola and Houston (2005) found that wage inequality in Mexico began to stabilize in the late 1990s, and one of the main reasons for this is that education levels increased sharply from 1998 to 2000.

The remainder of this paper is organized as follows. In Section 2, we extend Romer’s (1990) model to show that wage inequality rises with technology growth rates and outsourcing, but falls with educational investment. A temporary acceleration in educational investment, which deviates skilled labor supply and technology away from their balanced growth rates in the transition, thereafter leads to a permanently higher level of stocks of both skilled labor and technology. In Section 3, we show that after the economy again reaches its balanced growth equilibrium, the permanent increase in the relative supply of skilled labor depresses the wage inequality. Section 4 explains how the wage inequality is a malignant tumor to society, leading to substantial welfare loss for unskilled laborers. In Section 5, we conclude.

2. The Model

Feenstra and Hanson (1996) applied a Cobb-Douglas constant-returns-to-scale production function with exogenous technological change to illustrate how skill premiums change with outsourcing and technological shocks. In their model, the technology is neutral to skilled and unskilled workers. However, through the channel of international outsourcing trade, a neutral technology change becomes biased in favor of skilled labor.

However, there is some evidence, at least in the aggregate, showing increasing returns to scale in aggregate productions. For example, Caballero and Lyons (1992) noted that returns to scale rise at higher levels of aggregation, which they interpreted as evidence of enormous productive spillovers across industries. Basu and Fernald (1997) found that U.S. manufacturing shows some evidence of increasing returns, which is particularly true in durable goods. These results support Romer’s (1990) model, which has an endogenous technology function where profit-maximizing agents invest intentionally in research and development (R&D) to produce durable goods. The endogenous technological function, with its non-rival nature, implies that the output function must have increasing returns to scale. Therefore, we apply a version of Romer’s model (1990) rather than the traditional Cobb-Douglas production function to illustrate how international outsourcing and technological improvements affect the labor markets.
Let’s start with an aggregate-production function of the North as

\[ Y = \left[ A(L^\theta + M^\theta)^{\frac{1}{\theta}} \right]^{\alpha} K^{1-\alpha}. \]

(1)

Here, \( A \) denotes the number of ideas or stock of knowledge; while \( K \) denotes capital, also a form of durable goods. \( M \) is a measure of the quantity of outsourced tasks, which are imported from the South. It is feasible to assume foreign outsourced goods that substitute for unskilled labor in the North. Let \( 1 > \theta > \alpha \), which means that \( L \) and \( M \) are substitutes and there are diminishing returns to outsourcing (Either, 2005). Also suppose that total labor supply \( N \) has a constant growth rate \( n \), and \( N = L + H \), where \( L \) represents unskilled labor in final production and \( H \) represents skilled labor in the sectors of research and development, management, and marketing. The unskilled labor is engaged in the production of final goods, but the skilled labor is devoted to creating durable capital that raises the firm’s productivity.

At one point in time, the aggregate stock of knowledge is given by

\[ \dot{A} = \delta H^\rho, 1 > \rho > 0, \]

(2)

where \( \delta \) is a productivity parameter and \( \rho \) is a country-specific parameter denoting how skilled workers are efficiently employed. Jones (1999) referred it to as the “stepping on toes” effect (i.e., that duplication of R&D efforts is more likely when there are too many persons engaged in it). The duplication of activities reduces the efficient use of R&D resources. Additionally, we argue that the parameter of technology shock \( \rho \) also captures whether an economy has well-protected intellectual property rights, good management and efficient allocation of research funds, and so on. It is widely acknowledged that innovation (e.g., Jones, 1999) is encouraged if intellectual property rights are well protected, since entrepreneurs are assured that they will capture satisfactory private returns from the social returns that their innovations produce. With a legal system protecting patents and copyrights, entrepreneurs are more willing to invest in R&D and unveil their innovations in the form of patent applications, allowing all skilled labor to study freely the innovations described in the patent application. Protection of intellectual property ends up encouraging knowledge spillovers, that is, the “standing-on-shoulder” effect is enlarged, implying a larger \( \rho \). Without loss of generality, the parameter \( \rho \) captures all of the exogenous technology shocks in this paper.
An unskilled worker cannot become skilled simply in response to a rising demand for skilled workers. The necessary new skills can be acquired only through education or vocational training. The investment in education, denoted by $E$, helps to raise the supply of skilled labor and reduce the supply of unskilled labor. Along the balanced-growth equilibrium, $A$, $K$, $C$, $E$, and $Y$ grow at constant exponential rates along the balanced-growth path.

Suppose that the technology growth rate is given by $g_a = \frac{\dot{A}}{A}$ at any instant, and rewrite the equation (2) as

$$g_a = \delta \frac{H^\rho}{A}. \tag{3}$$

By logarithmically differentiating (3), we obtain the technological growth rate in balanced-growth equilibrium as

$$g_a = \rho n_H = \rho n, \tag{4}$$

where $n_H$ denotes the growth rate of the skilled labor supply and $n_H = n$ in the equilibrium.

We argue that an economy can make a temporary acceleration in the growth rate of educational investment at the expense of current consumption (i.e., the economy raises its saving rates), the growth rate of the skilled labor supply would deviate away from the total population growth rate in the transitional period, and the extent to which this would occur is dependent on increased educational investment. The corresponding enhancement in technology and labor endowment accompanies a short-term drop in consumption, all of which will return to their balanced growth path in the long term, leading to a permanent increase in both the technology stock and the relative supply of skilled labor. The skilled labor supply ends up being more relatively abundant than before, while the technology returns to its balanced growth rate. With a time lag, the supply of skilled labor will increase with an increase in educational investment:

$$n_H = n + \lambda (\frac{\dot{E}}{E} - g_E^*), \quad \lambda > 0, \tag{5}$$

where $g_E^*$ denotes educational investment’s balanced-growth rate in equilibrium. Plug (5) into (4), we obtain the technological growth rate in the transitional period:
\[ g_A = \rho n + \rho \lambda \left( \frac{\dot{E}}{E} - g_e^* \right). \]  

(6)

In transition, educational investment temporarily deviates away from its balanced growth path, such that \( \frac{\dot{E}}{E} > g_e^* \). However, in the new equilibrium, educational investment returns to its balanced growth rate \( \frac{\dot{E}}{E} = g_e^* \). Therefore, in the new equilibrium, technology’s balanced growth rate in (6) becomes

\[ g_A^* = \rho n. \]  

(7)

3. Relative Wages and Employment

In the Romer (1990) model, final goods production is in constant returns to scale, but durable goods are in monopolistic competition. Therefore, both unskilled labor and intermediate goods from the South receive the value of their marginal product. However, the prices of durable intermediate goods include a markup.

Let \( W_L \) be the wage rate of unskilled labor. We obtain the marginal product of unskilled labor from (1) as

\[ W_L = \alpha A^\alpha \left( \frac{K}{L} \right)^{1-\alpha} (1-z)^{1-\theta}, \]  

(8)

where \( \frac{K}{L} \) grows at the same rate as technology \( g_A \) in equilibrium. Here, we apply a method favored by Ethier (2005) to assume \( z = \frac{M^\theta}{L^\theta + M^\theta} \) as an outsource index. For simplicity, we normalize the price of final-goods to unity. Equation (8) then represents the real wage of unskilled labor in the North as well. Apparently, the wage rate of unskilled labor in the North is substituted by the outsourced goods from abroad, and the extent to which the international outsourcing is increasing in the elasticity of substitution \( \frac{1}{1-\theta} \). If the outsourced inputs are substituted for the South’s unskilled labor, then the North’s unskilled labor suffers from the substitution resulting from international outsourcing. Also implied in
(8), an increase in educational investment raises the technology stock and reduces the relative supply of unskilled labor, favoring the unskilled labor group with a higher real wage.

The next step is to find out the wage rate of skilled labor, \( W_H \). Jones (1995) assumed that a durable-good producer can purchase a patent for one period, and then sell the patent in the next period. Supposing \( P_A \) represents the initial investment cost in a new design of a durable good. Arbitrage requires equal returns, that is, \( rP_A = \pi + \dot{P}_A \), where the profit \( \pi \) must grow at the population-growth rate \( n \) because \( \frac{Y}{L} \) grows at the same rate as \( A \). On the other hand, \( \pi \) must grow at the same rate as \( P_A \), or, there will be no balanced equilibrium. Thus, in order to sustain \( \pi \)'s constant growth rate, \( P_A \) must grow at the same rate as \( n \) in equilibrium, such that \( P_A = \frac{\pi}{r-n} = \alpha(1-\alpha)\frac{Y}{A(r-n)} \).

The skilled workers equate the marginal benefits and costs in the durable-goods sector as

\[
W_H H = P_A \dot{A}. \quad (9)
\]

From above, the wage rate of skilled labor in the North is then given by

\[
W_H = \alpha(1-\alpha)\frac{g_A\ Y}{r-n\ H} = \alpha(1-\alpha)\frac{g_A}{r-n}A^\alpha L^\alpha K^{1-\alpha}H(1-z)^{-\frac{\alpha}{\sigma}}, \quad (10)
\]

where \( r \) is a constant capital rent. Note that the technological growth rate increases with favorable technology-related shocks on \( \rho \) and the growth of the skilled labor supply. In (10), the real wage for skilled workers in the North increases with international outsourcing trade, that is, \( \frac{\partial W_H}{\partial z} > 0 \).

Since the durable goods are in monopolistic competition, skilled workers \( H \) in the durable-goods sector should generate increasing returns to scale, implying \( \frac{\partial Y}{\partial H} > \frac{Y}{H} \). Taking the derivative of \( \frac{Y}{H} \) with respect to \( H \), we should observe \( \frac{\partial(\frac{Y}{H})}{\partial H} > 0 \) while \( \frac{\partial H}{\partial E} > 0 \). We then obtain
\[
\frac{\partial W_H}{\partial E} = \alpha(1-\alpha) \frac{g_A}{r-n} \frac{\partial Y}{\partial E} > 0 .
\] (11)

The (11) implies that the real wage of skilled workers also increases with an increase in educational investment. Note that the real wage of skilled labor might increase at a faster rate in the short-run transition than in the long-run equilibrium, while \(g_A > \rho n\) in transition but \(g_A = g_A^* = \rho n\) in the long run equilibrium.

In (8) and (11), acceleration in the educational investment rate raises the technology stock and reduces the relative supply of unskilled labor, favoring both unskilled and skilled labor with higher real wages in the long run. There exists an optimal educational investment rate along the balanced-growth path, which is based on an economy’s preference for consumption and income equality. However, the study of the political economy in a trade-off between smooth consumption and income redistribution is country-specific and beyond the scope of this paper.

From (8) and (11), we express the relative wage of skilled labor to unskilled labor in the North as

\[
\omega = \frac{(1-\alpha)g_A(\rho, n_H)}{(1-z)(r-n)} \frac{L(E)}{H(E)}. \tag{12}
\]

In (12), the wage inequality increases with favorable technology shocks on \(\rho\), that is, the technology shock directly generate a bias in favor of the skilled labor. The wage inequality in (12) also increases with the outsourcing trade, as indexed by \(z\).

Romer (1990) assumed that human capital can move freely between R&D and the final production sectors, so that \(\omega = 1\). However, in the real world, this assumption might be far from the truth, because wage inequality exists historically in most countries. Since it takes resources to educate unskilled labor to become skilled, the relative supply of skilled labor becomes relatively scarce. Further, international outsourcing can only substitute for unskilled labor. As a result, the imbalance between demand and supply for skilled labor leads to a skill premium between the skilled and unskilled labor groups.

In (12), a temporary acceleration in educational investment at the expense of current consumption (i.e., higher saving rate) cultivates more skilled labor and generates a higher technological-growth rate (\(\frac{dn_H}{dE} > 0\)) along the transition path until \(n_H = n\) in the new
equilibrium. Although the wage inequality might deteriorate in the transition while the technology growth accelerates temporarily, the skilled/unskilled labor endowment changes to a permanently higher level thereafter, further depressing the wage inequality. The permanent increase in the technological stock gives rise to the real wages of all labor groups. The rising real wages of all labor groups and the rising supply of skilled labor imply higher economic growth, so that the economy is capable of allocating more investments to education thereafter. It ends up in a virtuous circle, which has been observed in the cases of the Eastern Asian countries. For example, South Korea consistently and sharply increased educational investment (especially in basic education) from the 1970s to 1990s, while Mexico’s educational investment was sticky in the late 1980s. It turns out that Mexico saw a widening wage inequality in the late 1980s, but the wage inequality in South Korea leveled off, as shown in Figure 2.

Implicitly, our model illustrates a theoretical structure for the Kuznets inverted-U hypothesis (Kuznets, 1955), which states that the relationship between the level of economic development and wage inequality takes the form of an inverted U-curve. That is, wage inequality is expected to initially increase with economic growth in a country’s early stages of development, but would then decline from its peaks in the later stages. Nevertheless, we argue that a country’s wage inequality would not necessarily present the Kuznets inverse-U curve with respect to its economic development if there is sufficient educational investment. As in equation (12), an educational shock raises the relative supply of skilled labor (i.e., $\frac{L(E)}{H(E)}$), suppressing wage inequality. With a time lag, the educational shock also enhances technology growth (i.e., $g(n_H)$) to increase wage inequality in the transition. The net effect on wage inequality might be ambiguous. But, at this stage, if the country again implements more educational investment, relative supply of skilled labor accumulates further that will mitigate the effect of technology growth on wage inequality. Continuing this strategy to a point where the technology shock is dominated by the accumulation in relative supply of skilled labor, a country can sustain low wage inequality in most of time along the economic development.

Why did wage inequality in the U.S. increase in the 1980s but decrease in the 1970s, while outsourcing grew rapidly in both periods? Observing that educational attainment (e.g., attainment of a bachelor’s degree or more, attainment of a high school degree or more) in the U.S. accelerated in the 1970s but stagnated in the 1980s as shown in Figure 1, our model provides an explanation for the occurrence of such a phenomenon. We argue that the affect of education dominates that of outsourcing in the 1970s, leading to the decreasing wage inequality during that period. In contrary, U.S. educational attainment stagnated in the 1980s,
accompanied by increasing demand for skilled labor because of rising outsourcing trade, which worsened the wage inequality in the 1980s due to the imbalance between demand for, and supply of, skilled labor.

To prevent globalization-driven wage inequality, a government can increase its educational investment in order to generate a greater supply of skilled-labor and then depress the skill premium, but at the expense of current consumption - a trade-off that might not be preferred by every country.

4. Wage Inequality and Welfare

Krueger and Perri (2003) investigated the welfare consequences resulting from wage inequality in the U.S. over the last thirty years using a standard constant relative risk aversion utility framework. They included 81 distinct earnings classes in their sample, grouping these classes by education and sex. Their measures suggest that the increase in between-groups earnings inequality (i.e., the increase in the wage inequality) translates almost one-to-one into an increase of consumption inequality. The workers who suffer from permanent relative income falls (e.g. workers are unskilled) experience substantial declines in relative consumption by about 2% to 6%, with associated important welfare loss. However, households at the top end of the distribution (i.e., skilled workers) enjoy sizable welfare gains of similar magnitude to the losses of the poorest agents. Overall, Krueger and Perri (2003) argued that a majority of the population (about 60% of Americans) is on the losing side. The main part of these losses arises from the increase in between-group consumption inequality.

While the group of skilled labor is only a small minority of the population , a rising wage inequality implies an increasing welfare loss for an economy as a whole and the major burden is placed on the unskilled labor, heightening social and political tension. Meanwhile, Krueger and Perri (2003) also found that the government tax and transfer system may have become less progressive over the last 30 years, which cannot fully mitigate the increase in disposable earnings inequality. Their findings highlight the crucial role of educational investment in income redistribution, which substantially impacts the welfare of the unskilled labor group.

4. Conclusions

We extended Romer’s model (1990) to show that, when a government distributes educational investments equally among its population, the educational investment might temporarily
deteriorate the wage inequality, but permanently decrease it. Our model, where wage inequality rises with the technology growth rate and outsourcing, but falls with educational investment, sheds light on why wage inequality in the U.S. increased in the 1980s but decreased in the 1970s, although outsourcing grew rapidly in both the 1970s and 1980s.

Implicitly in line with the Kuznets inverted-U hypothesis, we argue that a temporary acceleration in educational investment at the expense of current consumption leads to an increased supply of skilled labor and consequently generates temporarily a higher technology growth rate, which might turn out to be a deteriorating wage inequality if the latter effect outpaces the former. However, the technology growth rate returns to its balanced-growth path in the new equilibrium, while the relative supply of skilled labor increases to a permanently higher level. The relative supply of skilled labor becomes more abundant thereafter, thus permanently depressing the wage inequality further. Nevertheless, as implied in our model, the country’s wage inequality would not necessarily present the Kuznets inversed-U curve with respect to its economic development if having sufficient educational investment.

As is well-known, international outsourcing leads to a greater demand for skilled labor, but under-investment in education leads to a shortage in the supply of skilled labor. As a result, the under-investment gives rise to a widening wage inequality in a country. The rising inequality, which is usually in favor of a small minority of the population, may heighten social and political tension and threaten a country’s long term development (Ogwang, 1995).

On the other hand, if a government is concerned with social welfare, more resources will be allocated to education equally. The more a country invests in education, the greater is the supply of skilled labor, and the lesser is the wage inequality. The larger the supply of skilled labor, the more abundant the technology stock, and the greater the real wages all of the labor groups in the economy can earn. The rising real wages of all labor groups and the rising supply of skilled labor imply higher economic growth, so that the economy is capable of allocating more investments to education thereafter. It ends up in a virtuous circle, which has been observed in the cases of Eastern Asian countries. However, the increase in educational investment is at the expense of current consumption, which is a trade-off that might not be preferred by every nation.
Endnotes

* Contact information: send correspondence to Chu-Ping Lo. E-Mail: cplo@ntu.edu.tw. Phone: (886)2-3366-2653. Chu-Ping Lo, Department of Agricultural Economics, National Taiwan University; K.C., Fung, Department of International Economics, University of California, Santa Cruz.

1. Feenstra and Hanson (1997) also estimated that expenditures on high-technology capital leading to an increase in the relative wage of non-production labor explain about 60% of its actual change from 1979 to 1990 in the U.S. They suggest that international outsourcing can account for 31% to 51% of the increase in the relative demand for skilled labor that occurred in U.S. manufacturing industries during the 1980s.

2. In the literature, the South must experience worsening wage inequality with an increasing in international outsourcing. This argument might contradict the experiences in Eastern Asian countries such as Taiwan, South Korea, and Hong Kong in the 1980s and 1990s.


4. The data source comes from the Korea National Statistical Office for Korea. For Mexico, the figures come directly from Chiquiar (2005, Bank of Mexico).

5. Jones (1998) argued that innovations are by no means limited to feats of engineering. For example, Sam Walton’s creation of the Wal-Mart approach to retailing is no less an innovative idea than those leading to advances in the semiconductor industry. Therefore, here we assume that all skilled workers (not only engineers or researchers) contribute to technological improvements.

6. Jones also argued that knowledge spillovers from the accumulated stock of knowledge lead to “standing on shoulders” effect.

7. The profit maximization for a durable-good producer is given by $\max \pi = P x - rx$, where $P$ is price of a durable good $x$ and $r$ is a constant capital rent. It is easy to find out the optimal $\pi = a(1 - a) \frac{Y}{A}$. 
8. \[
\frac{\partial (Y/H)}{\partial H} = \frac{dH}{dE} \left( \frac{\partial Y}{\partial H} / H \right) > 0.
\]

References


Figure 1. Educational Attainment and Wage Inequality in the U.S.
From 1960 to 1990

Note: educational attainment (with bachelor’s degree or more in the 25 to 29 year old population) represents an increasing supply of skilled labor, which we argue is due to an acceleration increase in educational investment. The data source for educational attainment is from the U.S. Census Bureau, Current Population Survey, and that of the wage ratio is from Feenstra and Hanson (1996).

Figure 2. Wage Inequality in Mexico and S. Korea: 1980 to 2000

Note: The relative wage in South Korea is calculated by the wage ratio between college and middle school graduates. In Mexico, the relative wage is the average wage ratio of skilled to unskilled labor hourly in manufacturing.\(^4\)
Table 1. Public Spending Per Student on Basic Education (U.S. dollars)

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<tbody>
<tr>
<td>South Korea</td>
<td>Primary/PGDP</td>
<td>0.50%</td>
<td>1.48%</td>
<td>5.97%</td>
<td>6.45%</td>
</tr>
<tr>
<td>Mexico</td>
<td>Primary/PGDP</td>
<td>0.49%</td>
<td>1.60%</td>
<td>1.28%</td>
<td>1.30%</td>
</tr>
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Sources: The figures of educational spending per primary student are from “A World Bank Policy Research Report: The East Asian Miracle: Economic Growth and Public Policy,” 1993. PGDP is from Penn World Table 6.1, denoting real income per capita (adjusted for terms of trade changes).