Can a Technological Change Harm Welfare?

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Abstract

We present a model with two production sectors, one more advanced than the other. Counter-intuitively, we find that a technological improvement in the less advanced sector may lower the long-run well-being in the economy, even though markets are fully competitive and individuals are rational. This occurs because this technological change lowers the incentive to direct investments towards the advanced sector.

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Introduction

Can a technological improvement be harmful to well-being in a perfectly competitive environment? Intuition suggest that it cannot, as, by definition, it enlarges the set of possible utility-bearing combinations, and the competitive environment makes these additional possibilities materialize. Yet, this intuition may not always be relevant, since it relies on static foundations, in the sense that it refers to a *given* supply of production factors. However, a technological change may also alter the composition of the supply of the relevant production factors, as it changes the incentives that investors face along the growth path of the economy.

In this article we present a theoretical model in which a technical change indeed lowers the long-run well-being in the economy, although all markets are fully competitive and individuals are rational utility-maximizers. The model features two production sectors, one more advanced than the other., and in each period firms and individuals choose in which sector to operate. Individuals have to invest in their education in order to be able to work in the advanced sector. We show that a technological improvement in the less advanced sector may lower the well-being in the economy (measured by the sum of the utilities of the individuals) in the long-run equilibrium of this model.[1] The reason for this is that this type of a technological improvement lowers the incentive to direct investments in physical and human capital towards the advanced sector.

Given the competitive and rational environment, this change in incentives and investments would not lower long-term utility if not for the other crucial element in the model, namely the plausible assumption of over-lapping generations. Due to this assumption,

[1] We measure economic well-being by the sum of utilities, and not via GDP per capita for two reasons. First, individuals are utility maximizers. Second, as the standard analysis in growth model shows, at the steady state a lower GDP may also allow for lower savings, and thus may be associated to higher consumption and utility.

individuals from sufficiently distant periods cannot directly trade with one another in order to exploit the possibilities borne out by the technological improvement.

There are many possibilities for a technological change which is biased towards the less advanced sectors. For example, biological improvements to crops may raise productivity in the agricultural sector and thus raise demand for low-skilled agricultural workers. Another example may be a new software for the operation of a delivery service may raise demand for low-skilled delivery personnel.[2]

So far, no study has shown how a technological improvement can harm well-being in the long–run. The closest result, derived in some models, e.g., Galor and Moav (2001), is that a technological improvement may cause a short-term decline in output due to a required period for the economy to adapt for the change. Yet, in all these models the long-term output is positively affected by the technological change, and the analysis is limited to the effect on output and not on well-being.

Several studies dealing with the uneven effect of globalization in developed and developing countries have found that openness to trade may lower well-being. This result is rather close to the one we derive here because openness to trade is very similar to technological improvement in the sense that both are supposed to widen the set of utility-bearing combinations, and therefore to raise welfare. Yet, as Galor & Mountford (2008) show, the rise in globalization during the second industrial revolution has lowered the incentives for investment in human capital in developing countries, and thus led to a long term decline in their per-capita GDP.[3] The mechanism they propose in the theoretical part of their study is similar in its nature to the one we offer here, with the following two main differences: First,

[2] For more details on prevalence of technological changes in low-skill intensive a sectors, see Acemoglu and Zilliboty (2001).
[3] See similar evidence in Blanchard & Olney (2017).

we look at the effect of a technological change and not on that of openness to trade; Second, we explicitly analyze the effect on welfare, and not merely on output.

The Model

The model presented here was introduced by Maoz and Sarid (2021), who used it to offer sectoral heterogeneity as an alternative explanation for Skill-Biased Technological Change in accounting for the joint dynamics of Total Factor Productivity, inequality and the wage-premium in recent decades in developed countries. They did not look at how a technological improvement affects the long-term well-being, which is the subject of the current study.

Consider a closed economy where aggregate output at time *t* is produced in two sectors, the advanced sector, indexed by *H*, and the less advanced sector, indexed by *L*. The production function is:

(1) $$Y_t = A_H \cdot \left(K_t^H\right)^{\alpha} \cdot H_t^{1-\alpha} + A_L \cdot \left(K_t^L\right)^{\alpha} \cdot L_t^{1-\alpha} ,$$

where $A_H > A_L$ are sector specific technology parameters, K_t^O is the capital employed at period *t* in sector $O \in \{H, L\}$, and H_t and L_t are, respectively, the quantities of workers in each sector. Markets are competitive, so factors are paid their marginal product:

(2) $$R_t = \frac{\alpha \cdot A_H}{\left(k_t^H\right)^{1-\alpha}} = \frac{\alpha \cdot A_L}{\left(k_t^L\right)^{1-\alpha}},$$

and

(3) $$w_t^O = (1-\alpha) \cdot A_O \cdot \left(k_t^O\right)^{1-\alpha},$$

where $k_t^O \equiv K_t^O / O_t$ is capital per worker in sector O, w_t^O is the wage for each worker in sector O. R_t is the rental rate of capital. Note from (2) that:

(4) $$k_t^H = (1+\gamma) \cdot k_t^L,$$

where $\gamma \equiv \left(\frac{A_H}{A_L}\right)^{\frac{1}{1-\alpha}} - 1 > 0$, and the inequality follows from $A_H > A_L$.

In each period a new generation of size 1 is born and lives three periods. In the first period of life, each individual chooses whether to acquire education or not, where education is mandatory for working in the advanced sector. In the second period of life, each individual works according to her education level, consumes, saves, and give birth to one offspring. In their third period of life all individuals retire and consume all their savings. Specifically, each individual *i* who is born at period *t*-1 maximizes the following utility function:

(5) $$U\left(c_t^i, c_{t+1}^i\right) = (1-\beta)\cdot\ln\left(c_t^i\right) + \beta\cdot\ln\left(c_{t+1}^i\right),$$

Under the budget constraint:

(6) $$c_t^i + \frac{c_{t+1}^i}{R_{t+1}} \le W_t^i,$$

where $0 < \beta < 1$, c_t^i is individual i's period t consumption, and W_t^i is individual i's life-long wealth, discounted to period t. Optimal consumption therefore satisfies:

(7a) $$c_t^i = (1-\beta)\cdot W_t^i$$ (7b) $$c_{t+1}^i = \beta\cdot W_t^i.$$

In order to acquire education, each individual i must incur the cost h^i at the first period of her life. Thus:

(8) $$W_t^i = \begin{cases} w_t^L & \text{if } i \text{ does not acquire education} \\ w_t^H - h^i\cdot R_t & \text{if } i \text{ acquires education} \end{cases}$$

By (5) and (6), an individual *i*, born at period t – 1, acquires education only if it raises W_t^i, and by (8), this occurs only if her education cost is below the following threshold:

(9) $$h^i < \frac{w_{t+1}^H - w_{t+1}^L}{R_{t+1}} \equiv \bar{h}_t \quad .$$

We assume that there is heterogeneity among individuals in their return to education and choose one of the simplest methods to model this heterogeneity by locating this heterogeneity in the cost of education. Thus, more abled individuals have lower education costs. We simplify further by assuming that the education cost of each individual *i* satisfies $h^i \sim U(0, 1)$. Consequently, the education threshold $\bar{h}_t$ equals H_{t+1}. From the assumption that each generation is of size 1, and that in each period only those at their second period life work it follows that $L_t = 1 - H_t$.

Applying (2) and (3) in (4), and then in $\bar{h}_t = H_{t+1}$ yields:

(10) $$k_t^L = \frac{\alpha}{(1-\alpha)\cdot\gamma} \cdot H_t \, .$$

Applying (9), (10) and $L_t = 1 - H_t$ in (1) yields:

(11) $$Y_t = A_L \cdot \left[\frac{\alpha}{(1-\alpha)\cdot\gamma}\right]^{\alpha} \cdot {H_t}^{\alpha} \cdot (\gamma \cdot H_t + 1).$$

The physical and human capital for period t+1 are formed during period t and satisfy:

(12) $$K^H_{t+1} + K^L_{t+1} + \tfrac{1}{2}\cdot \bar{h}_t^{\,2} = \beta \cdot \left[(1-\alpha)\cdot Y_t - \tfrac{1}{2}\cdot R_t \cdot \bar{h}_{t-1}^{\,2}\right] ,$$

where the LHS of (12) presents the three types of investments, with the period t expenditures on education satisfying $\int_0^{\bar{h}_t} h^i \cdot dh^i = \tfrac{1}{2}\cdot \bar{h}_t^{\,2}$. The RHS is period t individual savings based on the aggregate wages of the period t workers, $(1-\alpha)\cdot Y_t$, and their period t-1 debt of $\tfrac{1}{2}\cdot \bar{h}_{t-1}^{\,2}$.

Applying (2), (3), (4), (10), (11) and L_t = 1-H_t in (12) yields the following equation describing the dynamics of the economy:

(13) $$H_{t+1} = \frac{-\alpha + \sqrt{\alpha^2 + \phi \cdot \left(\gamma \cdot {H_t}^{1+\alpha} + 2\cdot {H_t}^{\alpha}\right)}}{(1+\alpha)\cdot\gamma} \equiv f(H_t),$$

where

(14) $$\phi \equiv (1+\alpha)\cdot \alpha^{\alpha} \cdot (1-\alpha)^{2-\alpha} \cdot \gamma^{2-\alpha} \cdot A_L \cdot \beta > 0$$

From (13) and (14) it immediately follows that $f(0)=0$ and $f'(H_t)>0$ for all $H_t > 0$, and that $\underset{H_t \to 0}{Lim} f'(H_t)=\infty$, and $\underset{H_t \to \infty}{Lim} f'(H_t)=0$. These properties imply that the dynamical system has at least one steady state equilibrium with $H_t > 0$. Maoz and Sarid (2021), prove that this steady state is unique and stable, implying that the economy converges to it monotonically. From the analysis so far it also follows that the unique steady state level of H determines a unique steady state level for each of the other variables in the model.

Technological Change and Welfare Analysis

Our focus in this study is on how a technological improvement in the less-advanced sector, i.e., a rise in A_L, affects the steady state sum of utilities of each generation. For that end we first calculate the indirect utility of individual i, born at period t, as a function of her wealth, W_t^i, and the interest rate R_{t+1}. Based on her optimal consumption captured by (7a) and (7b), her indirect utility is:

(15) $$V^i\left(W_t^i, R_{t+1}\right)=\ln\left(\beta^* \cdot {R_{t+1}}^{\beta} \cdot W_t^i\right),$$

where $\beta^* \equiv \beta^{\beta} \cdot (1-\beta)^{1-\beta}$. Based on that, we define and calculate the sum of the utilities of all the individuals born at period t-1 by:

(16) $$V_t^*\left(H_t, w_t^H, w_t^L, R_t, R_{t+1}\right) \equiv \int_0^1 V_t^i\left[W_t^i\left(w_t^H, w_t^L, R_t\right), R_{t+1}\right] \cdot dh^i$$

$$= \ln\left(\beta^* \cdot R_{t+1}\right) + \int_0^1 \ln\left[W_t^i\left(w_t^H, w_t^L, R_t\right)\right] \cdot dh^i$$

$$= \ln\left(\beta^* \cdot R_{t+1}\right) + \int_0^{\bar{h}_t} \ln\left(w_t^H - h^i \cdot R_t\right) \cdot dh^i + \int_{\bar{h}_t}^1 \ln\left(w_t^L\right) \cdot dh^i$$

$$= \ln\left(\beta^* \cdot R_{t+1}\right) + \left.\frac{\left(w_t^H - h^i \cdot R_t\right) \cdot \left[1 - \ln\left(w_t^H - h^i \cdot R_t\right)\right]}{R_t}\right|_0^{H_t} + \left(1 - H_t\right) \cdot \ln\left(w_t^L\right).$$

Simplifying this expression, and omitting time indexes, reveal that the steady state value of the sum of the utilities of an entire generation is

(17) $$V^* = \ln\left(\beta^* \cdot R\right) + \frac{w^H \cdot \ln\left(w^H\right) - \left(w^H - H \cdot R\right) \cdot \ln\left(w^H - H \cdot R\right)}{R} - H + \ln\left(w^L\right)^{1-H}.$$

Figure 1 shows a numerical analysis of the effect of A_L on the steady state level of V^*. As the figure shows, it is possible that V^* may decline in A_L. The intuition for this result is that a rise in A_L entails three different effects: First, a direct effect, which implies that for a given allocation of production factors, a higher A_L implies a higher output, and thus higher consumption and welfare; Second, an incentive effect, which implies that with a higher A_L, the incentives to invest physical and human capital in the advanced sector decline. This, in turn, results over time in a decline in output, consumption and welfare; Finally, with lower investment in human capital, individuals can direct more resources to consumption. This last effect does not affect output, but it does affect welfare.

As Figure 1 shows, for lower levels of A_L, the incentive effect is the dominating one, generating a decline in the steady-state levels of output and welfare. As A_L increases, this domination erodes, and at a certain point welfare increases with A_L, due to the allocation of more resources to consumption. Note that output continues to decline, as the allocation of resources to consumption does not affect output. Yet for higher levels of A_L, the direct effect is the dominating one, and therefore welfare and output rise with A_L.

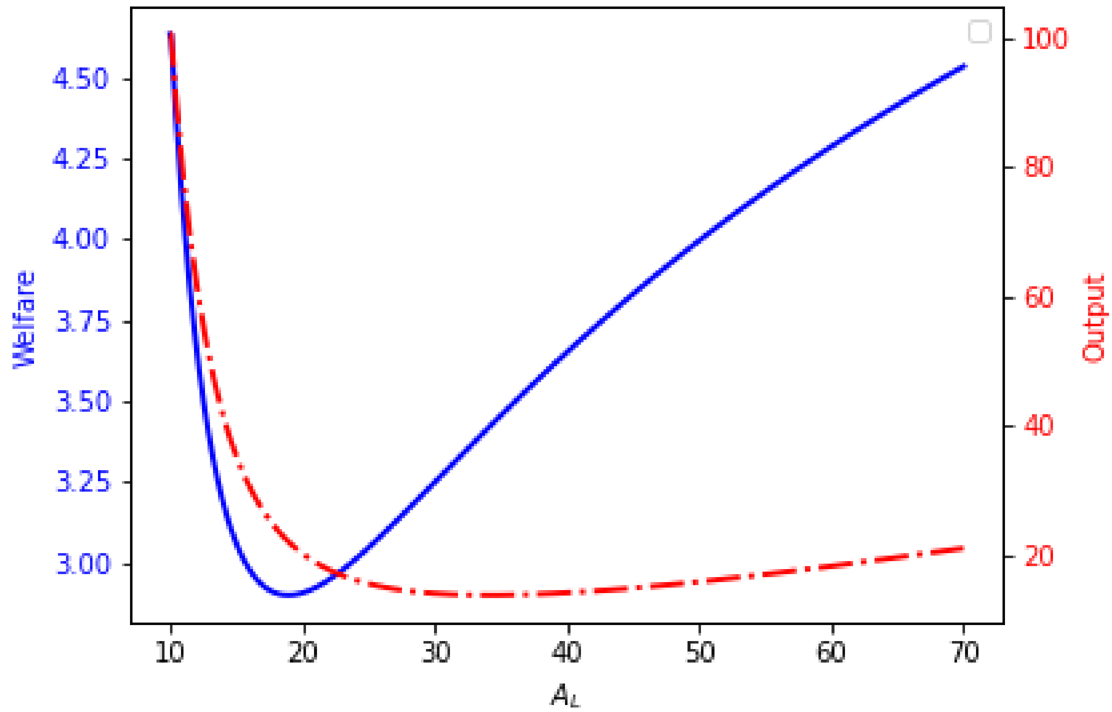

Figure 1: The Effect of Changes in A_L on Output per Capita and Welfare. Parameter values: ß=0.6, $\alpha = 0.5$, and A_H=100.

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