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Technological Progress, Factor Endowments and Structural Change: A Note

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Economic development is accompanied by structural change. The trade theoretic literature offers two major hypotheses—i.e. the factor–endowment and the total-factor-productivity—i.e. the factor-endowment and the total-factor-productivity—for explaining the stylised facts of structural change. This note revisits these hypotheses. In particular, it explores, with the help of a simple geometric apparatus, the analytical implications of the two hypotheses and draws out their striking similarities. It argues that although the literature has treated these two hypotheses as distinctly different, they are indeed analytically equivalent in the sense that they are both based on a similar type of shifts in the production functions. An important implication of this analytical equivalence is that, compounded with the data problems, it makes the task of empirical testing and discriminating between the two alternative hypotheses virtually impossible.

I. INTRODUCTION

Economic development entails structural change. There is a large economic literature on structural change, which include the notable contributions of Kuznets(1966), Kaldor (1961), and Chenery (1979). This literature has seen a resurgence of interest in recent writings (see, for example, Acemoglou and Guerrieri 2008, Buera and Kaboski 2008, Matsuyama 2008, and Ngai and Pissarides 2007). While this recent literature has broadened and deepened the scope of the enquiry, the essential focus has been to explain the stylised facts of structural change. These facts include: the positive correlation between

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internationally nontraded service prices and per capita income; the positive association between per capita income and relative labour productivity in the traded sector (in relation to the nontraded sector); the positive correlation between per capita income and the wage-rental ratio; and the positive association between the (nominal) share of services in consumption expenditure and per capita income.

International trade literature offers two fundamental hypotheses to explain these stylised facts. One is based on factor-endowment differences between countries—which is known as the called factor-endowment (FE) hypothesis; and the other is based on differences in total factor productivity (TFP) between countries in the production of nontraded goods—which is known as the TFP hypothesis. The FE hypothesis states that countries with larger factor endowments, per capita, of capital and other production assets will have higher incomes and higher prices for nontraded services (Bhagwati 1984, Harrod 1993, Kravis and Lipsey 1983, and Quibria 1990). The TFP hypothesis states that there are exogenous international differences in factor productivity between countries; however, those differences are smaller for nontraded sectors than for traded goods. These differences in factor productivity, the hypothesis states, translate into higher prices for nontraded goods as well as higher incomes for the richer countries (Balassa 1964, Bhagwati 1984, Harrod 1993, Samuelson 1964 and Quibria 1996).

This note revisits these hypotheses. In so doing, it explores for the first time, with the help of a simple geometric apparatus, the analytical implications of the two hypotheses and highlights the striking similarities between the two explanations. It demonstrates that the identical results yielded by both the hypotheses are essentially the outcome of the shifts in the production possibility curves generated either by particular patterns of technological progress or by changes in factor endowments. For both the hypotheses to yield a similar kind of results, it is obvious that they have to give rise to a similar type of shifts in the production possibility curves. This note shows that the shifts in the production possibility curves due to different rates of technological progress in traded and nontraded sectors can be approximated by a combination of changes in factor endowments. In view of this fact, the note argues that two explanations are analytically equivalent. Compounded with the data problem, this analytical equivalence makes the task of empirically testing and discriminating between the two hypotheses virtually impossible.

II. THE ANALYTICAL FRAMEWORK AND THE RESULTS

Before we provide a geometric exposition of the analytical framework and derive the results, it may be stated at the outset that this note exploits the following fact: cross-sectional differences between countries in factor endowments could be viewed as inter-temporal differences in factor endowments of a economy due to factor accumulation or due to differential TFP growth over time across sectors.

The analytical framework is based on the assumption that the economy in question is a "small" economy, which it means that it cannot influence world prices for internationally traded goods. If the economy is small, then one can construct a Hicksian composite of all traded goods at any given world price vector.[1] Analogously, one can also posit a utility function $U(C,H)$ that is a function the composite traded good C and nontraded good H.[2]

Assume that trade is always balanced—i.e. the value of exports equals import. Then given the economy's production possibility frontier (PPF), the optimal choice[3] of the nontraded good and the traded good occurs at E^o in

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[1] Thus, one can choose a unit of the composite good to represent any bundle worth a unit in terms of an arbitrary world numeraire. One can then derive a production function for the composite good, given a production function for each of the traded good, by maximising the value of output P of traded goods, (at the given world prices) for any chosen bundle of factor inputs Z devoted to the traded sector. Then the function $\phi(P,Z)$ that relates the maximum value of P to the factor input bundle Z is the production function for the composite.

[2] This is derived as follows: assume a social utility function $W(T,H)$ represents the utility derived from consuming a bundle of traded goods T and nontraded good H; from this, one can derive a composite utility function $U(C,H)$ that is a function of the consumption C of composite traded good and nontraded good H. All one has to do is to start from any given expenditure C on traded goods (in terms of world numeraire) and a vector of consumption of the nontraded good H and define $U(C,H) = \text{Max } W(T,H)$ subject to $C \geq$ Value of bundle T at international prices.

[3] This is more formally expressed as follows: given an aggregate factor endowment vector $\bar{Z}$ and production function $\phi(P,Z)$ for the traded composite good and a production function for the nontraded good, one can obtain the economy's production possibility frontier $F(P, H, \bar{Z}) = 0$ in the usual way. If trade is balanced, requiring that the value of exports should equal imports, then C has to equal P, and the optimal choice of P^o, H^o is determined by maximising $U(P,H)$ with respect to P and H subject to $F(P,H,\bar{Z}) = 0$.

Figure1. At this point the indifference curve $U^o\ U^o$ corresponding to maximised value of $U\ (P,\ H)$ touches the PPF, A^oB^o. The slope of the indifference curve and PPF at E^o is the slope of the common tangent TE^oT^1 denoted by π^o, which is the relative price of the nontraded good in terms of the world numeraire. In other words, π^o is the real exchange rate.

Let us for simplicity assume that there are just two factors, capital K and labour L. Let A^oB^o be the PPF for K^o, L^o. We assume that the production functions for the nontraded good and the traded composite are subject to constant returns to scale. Without loss of generality, let us further assume that both countries have identical labor endowments but different capital endowments. In particular, we assume that $L^o = L^1$ and $K^1 > K^o$. Next we assume that the traded composite is more capital intensive than the nontraded good. Then, from the Rybcyznski theorem we know, at the price π^o, the revenue maximizing levels of output of P and H will move along a straight RE^oR^1 through (P^o, H^o) as K is varied, in the segment RE^o (resp. E^oR') for variations in K above (resp. below) K^o. At a given π^o, the outputs corresponding to $K=K^1>K^o$ are represented by S' on RE^o in Figure 1.

If we now assume that the utility function $U(P, H)$ is homothetic, then the indifferences curves will be parallel to each other. This means that with the same price level, demand will move along the ray OE^o through the origin. If production takes places at S^1, then under balanced trade, demand will be at C^1 where the ray OE^o from the origin meets a line through S^1 with the slope π^o. Thus at the relative price π^o of the traded good, economy 1 will have an excess demand for (resp. excess supply of) the nontraded (resp. traded composite) good. Under the usual Walrasian stability assumptions about excess demand, to restore equilibrium the relative price of the composite traded good has to rise to $\pi^1 > \pi^o$, leading to equilibrium at E^1 (not shown in Figure 1).

Now from the Samuelson factor-price equalisation theorem we at know that the factor prices of economy 1 at S^1 are the same as that of economy at E^o. However, at E^o, the relative price of the labour-intensive nontraded good is π^1, which is higher than its value π^o at S^1. Next, we know from the Stolper-Samuelson theorem that at E^1 the real wage (resp. real rental) must be higher (resp. lower) than at S^1. Hence, economy 1 with a higher capital endowment has a *higher* equilibrium real wage and a *lower* rental rate than economy 0. With a higher wage-rental ratio, economy 1 will use more capital-intensive techniques of production in both goods, so that average productivity labour (resp. capital) will be higher (resp. lower) in economy 1 compared to economy 0. The value at price π^o of output at S^1 of economy 1 is clearly higher than that economy 0 at E^o. Since $\pi^1 > \pi^o$ the value of output at equilibrium E^1, which is also its income Y^1, will be higher than the value at π^o of output S^1 which in turn exceeds that of economy 0's output and income Y^o at E^o. Thus we have shown that economy 1, with a higher endowment of capital but the same endowment of labour as economy 0, will have:

(i) a higher relative prices of the nontraded good;
(ii) a higher real wage rate and a lower real rental per unit of capital;
(iii) higher-income, higher per capita income (if both economies have the same labour force participation rate as both have the same labour endowment) as well as higher average productivity of labour (resp. capital) in both goods.

Taken together these results imply a positive correlation between per capita income and (a) relative price of nontraded good, (b) real wages, and (c) average productivity of labour across countries that vary in their relative capital endowments, but face the same set of prices among internationally traded goods. These are cross-section correlations. But the same correlations could be viewed as time series correlations along the growth path of an economy that accumulates capital faster relative to labour, while facing an unchanging set of prices for traded goods.

If, in addition to assuming that $U(C, H)$ is homothetic, we assume that C and H are complementary, then the share of nontraded good in consumption will rise as its relative price rises. With this assumption there will also be a positive correlation between per capita income and the share of nontraded good in consumption.

Let us now consider economy 2 which has the same factor endowments as economy 0, but its technology of production of traded composite has a higher TFP. One could equivalently consider the case in which the two countries differ in TFP in the technology of production of both goods, but the TFP in traded good relative to that in nontraded good is higher in economy 2 compared to economy 0. For simplicity of exposition, we assume that the only difference between the economies is their differences in TFP in the traded good sector.

By definition, the higher, Hicks-Neutral TFP in the traded-good sector in economy 2 means that its isoquant map for the traded good will be the same as that of economy 0 except that each isoquant will correspond to a higher level of output in economy 2, compared to same isoquant of economy 0 by a proportion of λ. This has the following implications. First, regardless of the difference in TFP, both countries will use the *same capital intensity of production in each good if they face the same wage/rental ratio*. Second, the PPF of economy 2 could be obtained from that of economy 0 by raising the output of the traded good, corresponding to any given level of output of the nontraded good, by a factor of λ. As such, at any level of output of the nontraded good, the slope of the PPF of economy 2 will be higher by the same factor.

Assume that economy 0 is in equilibrium at E^o with relative price π^o of non traded good. At price π^o, production in economy 2 will take place at S^2, which represents a lower output of nontraded good compared to H^o. Again, given the homothetic utility function $U(C,H)$, it follows that demand at prices π^o will be at C^2, C^2 being the point where the ray OE^o from the origin meets S^2C^2, a straight line through S^2 with slope π^o. Assuming that trade has to balance, consumption and production have to equalise. But at π^o, there will be excess demand for (resp. supply of) the nontraded good (resp. traded good). Assuming Walrasian stability, for restoring equilibrium the relative price of the nontraded good will have to increase to $\pi^2 > \pi^o$.

Now with $\pi^2 > \pi^o$ it is easy to see that economy 2 will have a higher income and higher per capita income (again under the assumption of identical labour force participation rates) as compared to economy 0. This follows from two reasons: first, if economy 2 faced π^o, its income at S^2 will be higher than that of economy 0; second, as the relative price of nontrades goods increases to π^2, its income will increase further.

Now from $\pi^2 > \pi^o$ we cannot, however, immediately infer whether equilibrium output in economy 2 of the nontraded good, H^2, will exceed or fall short of H^o. At an output H^o of the nontraded good, the slope of the PPF of economy 2 at S^3, as noted earlier, is $\lambda\pi^o$ with $\lambda > 1$ so that $\lambda\pi^o > \pi^o$. Thus in a neighbourhood or both sides of H^o, the slope of the PPF will exceed π^o; therefore, $\pi^2 > \pi^o$ does not preclude H^2 exceeding or falling short of H^o. As the PPF of economy 2 is an upward shift of the PPF of economy 0 by λ, it is evident that $H^2 \gtreqless H^o \Leftrightarrow \pi^2 \gtreqless \lambda\pi^o$. Similarly, follows that the output P^2 of traded composite satisfies $H^2 \gtreqless H^o \Leftrightarrow P^2 \gtreqless \lambda. P^o$.

Next, we show that the consumption of the nontraded good increases as the relative price of the nontrade good increases. This in turn implies that the *ratio* of the value of consumption of the nontraded good to that of the traded composite increases as well. That is: $\frac{\pi^2 H^2}{P^2} > \frac{\pi^\circ H^\circ}{P^\circ}$. This follows from two factors. First, consumption C^2 and C° respectively of the traded composite in countries 2 and 0 equal their production P^2 and P°. Second, with identical homothetic tastes, the ratio of consumption of the nontraded good to the consumption of the traded good in economy 2 is the same as that of economy 0 at any common price. Now $\frac{\pi^2 H^2}{P^2} > \frac{\pi^\circ H^\circ}{P^\circ}$ together with $H^2 \leq H^\circ$ would imply $\frac{\pi^2}{\pi^\circ} > \frac{P^2}{P^\circ}$. But we have shown earlier $H^2 \leq H^\circ$ implies $\frac{P^2}{P^\circ} > \lambda > 1$ and $\frac{\pi^2}{\pi^\circ} \leq \lambda$, which in turn means $\frac{\pi^2}{\pi^\circ} < \frac{P^2}{P^\circ}$, a contradiction. Hence, $H^2 > H^\circ$. In the special case where C and H are *perfect* complements so that indifference curves are 'L' shaped, equilibrium of economy 2 will in fact be at S^4 where the ray OE° meets the PPF of economy 2.[4]

With $H^2 > H^\circ$, it immediately follows that real wages (resp. real rental) in equilibrium of economy 2 will exceed (resp. fall short of) that of economy 0. This is seen as follows. At H^2, the slope of the PPF of economy 2 exceeds its slope $\lambda\pi^\circ$ at H° and hence by the Stolper-Samuelson theorem, it follows that real wages (resp. real rental) at H^2 will be higher (resp. lower) than that at H°. But at H° the wage-rental ratio in economy 2 is the same as that of economy 1. With an equilibrium higher wage-rental ratio at H^2, economy 2 will use more capital-intensive techniques of production than economy 0, and hence average productivity of labour (resp. capital) will be higher (resp. lower) than that in economy 0 in the production of either commodity. Thus with the additional assumption of complementarity of demand we have established all the results under the TFP hypothesis that we proved under the FE hypothesis.

Finally, it should be noted that the basic factor that drives the behaviour of the relative price of the nontraded good under the FE and TFP hypotheses as the same. It is the fact the at a *given* relative price of the nontraded good, an

4 The reason why one needs the complementary assumption is seen by assuming the extreme case of perfect substitution. For an interior maximum to occur at E°, the indifference curve has to be $TE^\circ T^1$ with slope π°. As such, equilibrium for an economy will occur at H^2 so that $H^2 < H^\circ$.

economy with a higher endowment of capital relative to labour or an economy with a higher relative total factor productivity in the traded good than another, will have a larger output of the traded good. In the first case, the output of the traded good has to be larger to keep the two factors fully employed at unchanging factor intensities (as long as the traded good is labour intensive). In the second case, at given factor allocations and prices, the relative output of the traded good is higher because of the higher relative total factor productivity in the production of the traded good.

III. CONCLUSION

This note has shown, with the help of a simple geometric apparatus, that many of the important stylised facts of structural change from economic development can be explained by two alternative hypotheses advanced in traded literature. These two alternative explanations–i.e. the FE hypothesis and the TEP hypothesis–are both based on a similar type of shifts in the production functions. Given this isomorphic nature of explanations, the note argues that the two major hypotheses advanced in the literature are analytically equivalent. An important implication of this analytical equivalence is that, compounded with the data problems, it makes the task of empirical testing and discriminating between the two alternative hypotheses virtually impossible.

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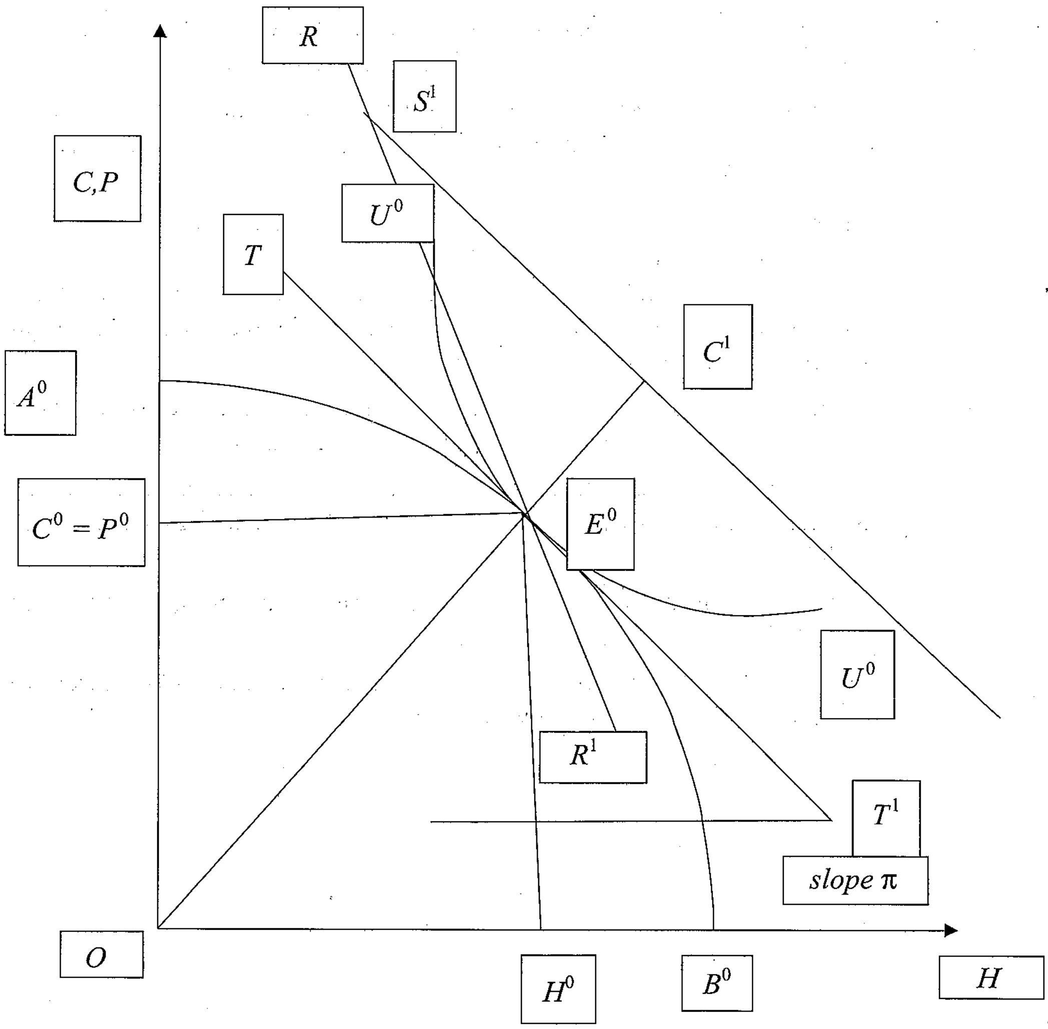

Figure 1

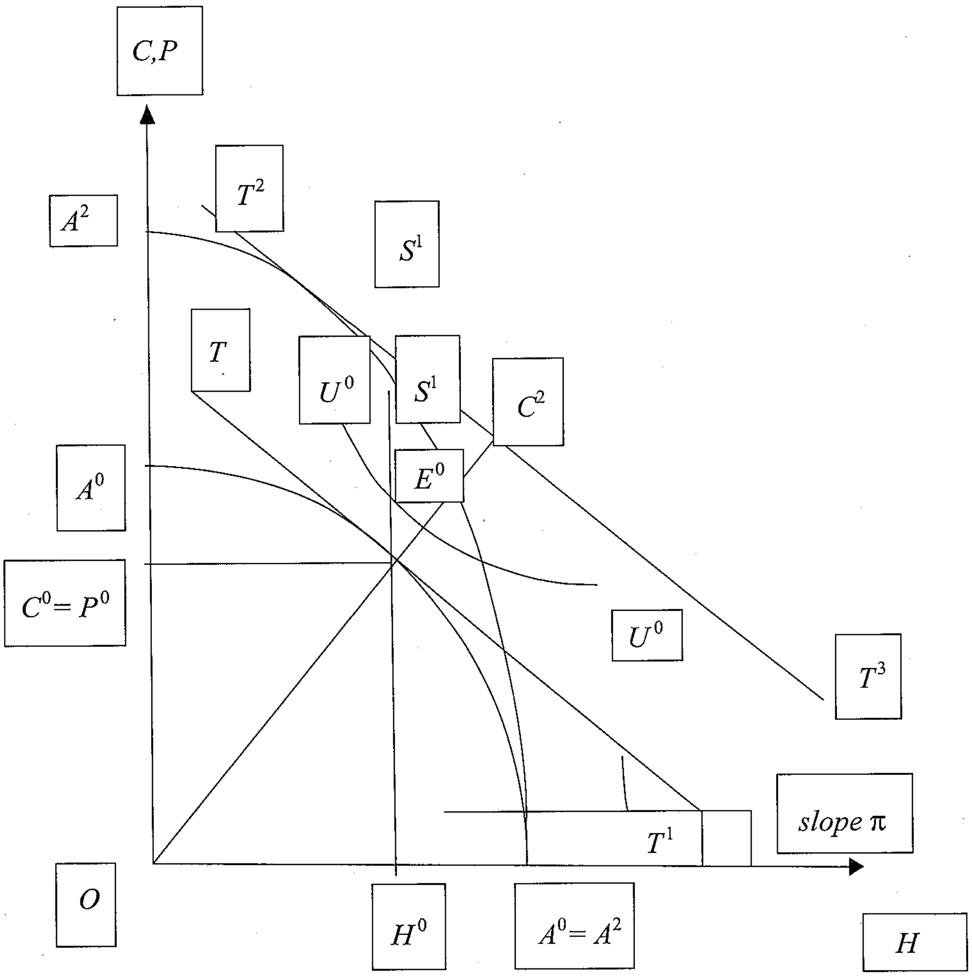

Figure 2