Neutral Technological Change and the Skill Premium

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Abstract: We construct a two sector general equilibrium model in which one sector produces a homogeneous good and the other sector produces a vertically differentiated good. We demonstrate that uniform (across sectors) and (Hicks) neutral technological change can cause an increase in the skill premium.

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1. Introduction.

One of the most widely studied questions of the last decade concerns the reasons behind the substantial increase in wage (and income) inequality in OECD countries during the last twenty years. Juhn et.al. (1993) document for the U.S. that, after controlling for education and experience, wage differentials have been rising continuously since the early 1970's. Since many studies have found that is difficult to account for the increase in the skill premium – defined as the wage of skilled labour relative to unskilled labour – on the basis of observable variables, skill biased technological change has been proposed as the main explanation (see, also, Berman, Bound and Griliches (1994) and Berman Bound and Machin (1998) for international evidence).[1] Autor, Katz and Krueger (1997) and Machin and Van Reenen (1998) argue that the widespread use of computers is a manifestation of skill biased technological change responsible for the rise in the skill premium. Moreover, as a matter of logic, Aghion and Howitt (1998) state "Now, if technological change is to generate an increase in wage inequality, it must be because technological change is biased toward certain skills or specialiations, in the sense that it reveals and enhances new differences in abilities among workers across or within educational cohorts."(p. 299).

In this paper we demonstrate that technological change need not be biased in order to generate increases in wage inequality. More specifically, we show in the context of a two-sector general equilibrium model that uniform (across sectors) and (Hicks) neutral technological change can cause an increase in the skill premium. We achieve this by assuming that one of the sectors produces a vertically differentiated

[1] The view that increased international competition with unskilled workers in developing countries is responsible for the rise in the skill premium has been largely discredited. (Johnson, 1997). For an argument in support of this view, see, Wood (1994).

good, and that higher quality varieties of this good are more skilled labour intensive than lower quality varieties. An increase in productivity which results in an increase in real incomes generates demand for higher quality varieties and therefore an increase in the (relative) demand for skilled labour. The resulting increase in the skill premium is thus caused not by changes in relative marginal products but by a product demand induced shift towards higher quality products.

In the rest of the paper we first present the model (section 2) and then we derive the effects of technological change on the skill premium (section 3). The final section offers some concluding comments.

2. The Model.

We construct the simplest possible model capable of illustrating the main idea of the paper. We assume a closed economy which produces and consumes two goods (X and Y) with the use of skilled labour (S) and unskilled labour (L). We assume that perfect competition prevails in all markets.

a. Production.

Good X is a homogeneous good produced under constant returns to scale,

$$X = AS^{a}L^{1-a} \qquad 0 < a < 1 \tag{1}$$

with A being a productivity parameter reflecting the state of technological knowledge. The cost minimizing factor demands for skilled (S_x) and unskilled labour (L_x) corresponding to the above production function are

$$S_x = \left(\frac{w}{r}\right)^{1-a}\left(\frac{a}{1-a}\right)^{1-a} A^{-1}X \tag{2}$$

$$L_x = \left(\frac{w}{r}\right)^{-a}\left(\frac{a}{1-a}\right)^{-a} A^{-1}X \tag{3}$$

where w is the wage of unskilled labour and r is the wage of skilled labour. The average cost function corresponding to equation (1) is

$$\mathrm{AC_x} = \left(\frac{w}{1-a}\right)^{1-a}\left(\frac{r}{a}\right)^{1-a} A^{-1} = P_x \tag{4}$$

with the assumption of perfect competition ensuring that it will be equal to the price of good X, P_x.

Good Y is a vertically differentiated good which can be offered by all firms at various quality levels. We assume that quality is measured by an index Q ≥ 0 and that, there is complete information regarding the quality index. We further assume that average costs depend on quality and that, for any given quality level, the average is independent of the number of units produced. These assumptions can be captured by the following Leontief-type production function,[2]

$$Y_Q = A.\min\left\{\frac{S}{gQ^{\epsilon}}, \frac{L}{d}\right\} \qquad ?, d, \in > 0 \tag{5}$$

?n equation (5), Y_Q denotes the number of units of quality Q produced, A is the same productivity parameter as in equation (1) and ?,d, and ∈ are parameters. This particular specification of production technology implies that as quality increases, more units of skilled labour are required to produce each unit of the Y good. This assumption is consistent with the fact that increases in quality – for a given state of technological capability – involve the employment of a larger number of personnel not only for the production of a higher number of features attached to each good (e.g. electric windows, air bags, ABS etc. in the case of automobiles) that directly absorb skilled labour, but also to the development and refinement of these features. By

[2] Assuming a Cobb-Douglas production function would only complicate the algebra without adding anything of substance to the analysis. Nevertheless, the assumption of fixed-coefficient technology necessitates the existence of another sector in which factor use depends on factor prices. Otherwise the ratio of factor prices would be indeterminate.

contrast the number of units of unskilled labour required to produce a unit of the good are independent of quality and equal to $d?^{-1}$. ?his is a strong assumption, and it is adopted here for the sake of convenience. It can be thought of as capturing the idea that the number of unskilled workers employed (e.g. cleaners, security guards, clerks, drivers of merchandise, workers doing simple assembly operations etc.) is to a large extent independent of the quality of the good. In any case, all that is needed for the results of this paper, is that higher quality varieties of the Y good require a higher proportion of skilled to unskilled labour than lower quality varieties. This implies that a production function of the type Y_Q = A.min $\{S/?Q^{\in}, L/dQ^{\mu})$ would secure us the same results, as long as, $\in > \mu$.

?quation (5) implies that the (average cost, and) price at which each variety of good Y will be offered is

$$P(Q) = (r?Q^{\in}+wd)?^{-1} \tag{6}$$

? ?te that although P(Q) is increasing in Q, the "price per unit of the quality index" (=P(Q)/Q) can be either decreasing or increasing depending on the value of parameter $\in$.

b. Demand.

All households are assumed to have identical preferences, and to be endowed with either a unit of skilled or a unit of unskilled labour, which they offer inelastically. Following Flam and Helpman (1987) we assume that the homogeneous good is divisible, whereas the quality-differentiated product is indivisible and households can consume only one unit of it. Households are assumed to choose the quantity they want to consume of the homogeneous product (C) and the quality level of the differentiated good (Q) which solves

$$\max U=C^{1-\mu}Q^{\mu} \qquad \text{s.t. } P_xC + P(Q) = m \qquad 0 < \mu < 1 \tag{7}$$

where m=r in the case of households (consumers) owning one unit of skilled labour, and m=w in the case of households owning one unit of unskilled labour. Note that although the price P_x remains constant no matter how much the household consumes of good X, the price “per unit of the quality index” P(Q)/Q which the consumer pays is not constant. Nevertheless, the household knows the exact correspondence between quality and price. All perfectly competitive firms are assumed to announce to the households a price list linking quality to price as given by equation (6). The budget constraint faced by the household will be non-linear in this case. In order to avoid the possibility of more than one point of tangency between the budget constraint and an indifference curve we assume that P(Q)/Q is increasing for all values of Q. [3]

The demand functions for each type of household (S and L) arising from programme (7) are

$$Q_S = \left[\frac{Am\ (r - wdA^{-1})}{rg\,((1-m)\in +m)} \right]^{1/\in} \tag{8}$$

$$Q_L = \left[\frac{Am\ (w - wdA^{-1})}{rg\,((1-m)\in +m)} \right]^{1/\in} \tag{9}$$

$$C_S = \frac{(1-m)\in (r - wdA^{-1})}{P_x((1-m)\in +m)} \tag{10}$$

[3] A necessary condition for this is that $\in > 1$. But this is not sufficient since even if $\in > 1$, unskilled labour costs can initially (at low levels of Q) be a large part total labour costs, so that (initially) P(Q)/Q is decreasing in Q. We, therefore, assume that this is not the case.

$$C_L = \frac{(1-m)\in (w - wdA^{-1})}{P_x((1-m)\in +m)} \tag{11}$$

Assuming that positive "amounts" of quantity and quality are chosen, we have to impose the restrictions that r-wd? $^{-1}$ > 0 and 1-d? $^{-1}$ > 0. These will hold if the initial productivity level enables (even the unskilled) workers to afford the lowest quality at which the differentiated good can be produced.[4]

3. Equilibrium.

Letting $\overline{S}$ and $\overline{L}$ denote the fixed aggregate supplies of skilled labour and unskilled labour (respectively), the equation describing equilibrium in the market for the homogeneous good X is

$$X = \left[\frac{(1-m)\in (r - wdA^{-1})}{P_x((1-m)\in +m)}\right]\overline{S} + \left[\frac{(1-m)\in (w - A^{-1}wd)}{P_x((1-m)\in +m)}\right]\overline{L} \tag{12}$$

with the right-hand-side of equation (12) representing the aggregate demand for good X. This is equal to the quantities demanded by each skilled and unskilled worker (household) – as given by equations (10) and (11), multiplied by the available supply of workers in each group.

With respect to good Y, equations (8) and (9) determine the two "market clearing" varieties (identified by Q_S and Q_L) of the good that will be produced in equilibrium. The number of units produced and consumed of each variety will be equal to the number of skilled and unskilled workers, respectively.

The conditions describing equilibrium in factor markets can be written as

[4] ? ssuming that unskilled workers can not afford the lowest quality at which the differentiated good can be offered is a situation typical of many LDC's (i.e., unskilled workers can not afford even the lowest quality ovens, automobiles, stereos etc.) Introducing such features into the model may be a worthwhile extension of the present paper.

$$\bar{S} = S_x + \left[\frac{m(r - wdA^{-1})}{r((1-m)\in +m)}\right]\bar{S} + \left[\frac{m(w - wdA^{-1})}{r((1-m)\in +m)}\right]\bar{L} \tag{13}$$

$$\bar{L} = L_x + A^{-1}d\,(\bar{L} + \bar{S}) \tag{14}$$

Note that in writing equation (13) we have used equations (8) an (9), which implicitly define the amount of skilled labour required to produce a unit of quality Q_s (bought by each skilled worker) and a unit of quality Q_L (bought by each unskilled worker).

The model is now solved to determine the effects of changes in the common productivity parameter A on the skill premium, which we define as $F \equiv r/w$. To solve the model we substitute first equations (4) and (12) into equation (2), and then we substitute the resulting expression for S_x into equation (13). The outcome is equation (15) below which expresses the relationship between the skill premium F and the productivity parameter which keeps the market for skilled labour in equilibrium; [5]

$$\bar{S} = F^{-1}\left[\frac{a(1-m)\in +m}{(1-m)\in +m}\right][(F - ?^{-1}d)\bar{S} + (1 - ?^{-1}d)\bar{L}] \tag{15}$$

From equation (15) we find that

$$\frac{d\Phi}{dA} = \frac{A^{-2}d\,(\bar{S} + \bar{L})[(1-m)\in +m]}{\Phi^{-1}[(\Phi - A^{-1}d)\bar{S} + (1 - A^{-1}d)\bar{L}](1-a)(1-m)\in} > 0,$$

i.e. neutral technological change results in an increase in the skill premium. Equation (15) also implies that in the face of continuing increases in productivity, continuing

[5] Walras' law ensures that the value of F which results from "solving" equation (15), guarantees equilibrium in the market for unskilled labour as well. It can also easily be established that a solution for F exists, and that it is unique.

increases in wage inequality can be avoided only through continuing increases in the (relative) supply of skilled labour.

4. Conclusion.

This paper has constructed a two-sector general equilibrium model in which neutral technological change results in an increase in the skill premium. The mechanism generating this result hinges on the assumption that higher quality products are more skill-intensive than lower quality products. Uniform and neutral productivity increases across both sectors (which result in increases in real incomes of all workers) generate demand for higher quality products. The ensuing increase in the (relative) demand for skilled labour necessitates an equilibriating increase in the skill premium.

Our framework can also be adapted for the study of the effects of technological change on the unemployment rates of skilled and unskilled labour. Minimum wage legislation (aimed at protecting unskilled workers) may prevent the skill premium from adjusting in the face of technological progress, and therefore result in the large increases in unemployment rates amongst unskilled workers which have been observed in European countries.

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