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TECHNICAL CHANGE AND EMPLOYMENT IN STEEL, AUTOS, ALUMINUM, AND --ETC(U)

MAR 81 J M JONDROW, R A LEVY, C HUGHES

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TECHNICAL CHANGE AND EMPLOYMENT IN STEEL, AUTOS, ALUMINUM, AND IRON ORE

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INTRODUCTION

Technical change, making possible increased output from existing resources, enhances the potential standard of living for society. Yet in the particular industries where technical change is occurring, there are conflicting effects: (1) the price of output will fall so that more is demanded and (2) the demand for some or all inputs for given output will be reduced. With respect to labor, the first effect increases demand, the second diminishes it.

This paper presents estimates of the net effect of technical change on labor demand in four industries: steel, autos, aluminum, and iron ore. Using an economic model of these industries (which takes account of the linkages among them), we estimate what would have been the effect on employment if no technical change occurred in each since 1959.

We find that if technical change had been suppressed, output and employment in two of the industries (aluminum and iron ore) would have been drastically reduced, largely because of an inability to compete with imports. The other two (steel and autos) would have suffered large drops in output, but their employment would be changed by less than 4 percent. In other words, suppressing technical change in steel and auto would have lowered output and raised employment per unit output, with the effects more or less cancelling out.

COST, FACTOR DEMAND, AND TECHNOLOGY

The economic model involves several types of equations: total cost, factor demand, output demand, import demand, and price (supply). We start with the equations for cost, factor demand, and technical change. For steel, aluminum, and autos, these equations are drawn from a translog cost function:[1]

$$\begin{aligned} \ln C = {} & \alpha_0 + \Sigma_i \beta_i \ln P_i + \beta_Q \ln Q + \beta_T T + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j \\ & + \Sigma_i \gamma_{iQ} \ln P_i \ln Q + \sum_i \gamma_{iT} \ln P_i T + \frac{1}{2} \gamma_{QQ} (\ln Q)^2 \qquad (1) \\ & + \gamma_{QT} \ln Q \; T + \frac{1}{2} \gamma_{TT} \; T \end{aligned}$$

The cost function includes input prices, output --allowing for nonconstant returns to scale, and T, a time trend, to represent technical change.[2,3]

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[1] The time subscript on each variable is suppressed, here and for the entire paper.

[2] In a related paper we test direct measures of technical change for autos and steel [6].

[3] The particular version of the translog used follows Gollop and Roberts [2].

Factor demand is easily obtained by differentiating equation (1) with respect to $\ln P_i$. This gives an equation for the ith factor share:

$$V_i = \beta_i + \Sigma_j \gamma_{ij} \ln P_j + \gamma_{iQ} \ln Q + \gamma_{iT} T \quad i=1,\ldots,n \quad (2)$$

We complete the system with an equation describing the rate of change in productivity. The equation shows how the change in cost net of input prices (called W) depends changes in scale and changes in technology. The equation is:

$$W = V_Q \frac{d\ln Q}{dT} - V_T \quad (3)$$

where $V_Q = \frac{\partial \ln C}{\partial \ln Q} = \beta_Q + \Sigma_i \gamma_{iQ} \ln P_i + \gamma_{QQ} \ln Q + \gamma_{QT} T$ (4)

and $V_T = \frac{\partial \ln C}{\partial T} = \beta_T + \Sigma_i \gamma_{iT} \ln P_i + \gamma_{QT} \ln Q + \gamma_{TT} T$ (5)

Estimating the system of equations given by (1), (2), and (3) provides the parameters necessary to characterize technical change, cost, and factor demand.

In order to use equations (1)-(5) to estimate the effect of technical change on employment, we take the total differential of each equation. The differential operator (Δ) represents a difference between two time paths resulting from different levels of technical change after 1959. It therefore corresponds to the type of differences found in comparative static analysis, not a change over time.

Differential Steel Cost and Factor Demand

$$\Delta \ln C = V_Q \Delta \ln Q - \sum_{t=1}^{T} \Delta V_t \qquad (6)$$

$$\Delta V_L = \gamma_{LQ} \Delta \ln Q + \gamma_{LT} \Delta T \qquad (7)$$

$$\Delta V_K = \gamma_{KQ} \Delta \ln Q + \gamma_{KT} \Delta T \qquad (8)$$

$$\Delta V_M = -(\Delta V_L + \Delta V_K) \qquad (9)$$

The sum in equation (1) is taken from 1959 to the present. Since V_t is the actual rate of technical change, and the rate in the absence of technical change is 0, the sum is the change over time in the cumulated effect of technology on cost. The sum simply recovers the level of the cumulated effect.

OUTPUT DEMAND

The equations for output demand (including competition with imports) are drawn from the economic literature.

The remaining equations (and the estimated parameters) come from other sources. For steel, demand is specified in two equations, one describing the relation between domestic (Q_S) and imported steel (M_S), the other describing the dependence of steel as a whole on the steel price ($\overline{P}_S$).[1] Steel as a whole is defined as a CES aggregate of imported and domestic steel (S). The steel price is defined as a divisia index of the imported (PM_S) and domestic steel price (P_S).[2] These equations specifying steel demand are provided below.

Steel Demand

Import Substitution

$$\ln \frac{M_s}{Q_s} = C_0 + .994\ln \frac{P_s}{PM_s} + .454\ln \frac{M_s}{Q_s}_{-1} + .256\ln \frac{M_s}{Q_s}_{-2} + .113\ln \frac{M_s}{Q_s}_{-3} \qquad (5)$$

Demand for Steel Aggregate

$$\ln S = C_1 + .446\ln\overline{P}_s - .294\ln S_{-1} + .23\ln(Q) \qquad (6)$$

[1] The equations representing the demand for steel are taken from [4].

[2] Actually the discrete approximation to the Divisia index, the Tornquist index, is used.

Definition of Aggregate Steel Quantity (S)

$$S = \left(.4M_s^{.83} + .6Q_s^{.83}\right)^{1.2} \qquad (7)$$

Definition of Aggregate Steel Price

$$\ln(\overline{P}_s) - \ln\overline{P}_s(-1) = (1-SM_s)(\ln P_s - \ln P_s(-1)) \qquad (8)$$
$$+ (SM_s)\ (\ln PM - \ln PM_{-1})$$

Import Share

$$SM_s = \frac{P_s M_s}{PM_s M_s + P_s Q_s} \qquad (9)$$

These equations are totally differentiated and then used in the simulation.[1]

For example, equation (5) in differenced form (with the subscript s suppressed) will be

$$\Delta\ln M = \Delta\ln Q + .994\Delta\ln P + .454(\Delta\ln M_{-1} - \Delta\ln Q_{-1})$$
$$+ .256(\Delta\ln M_{-2} - \Delta\ln Q_{-2}) + .113(\Delta\ln M_{-3} - \Delta\ln Q_{-3})$$

The last set of equations in the steel model are simple identities relating the difference in the logarithm of say, price, and its simple difference, or

$$\ln P = \Delta P/P \qquad (10)$$

[1] It should be noted that the equations outlined above are not the complete equations which might be used to describe steel demand, for example, but rather a shortened version that includes only those variables which are affected by technical change.

This relationship is a good approximation for small changes, is used for imports (M), prices (P), share of imports (SM), and output (Q).

Motor Vehicles

Both motor vehicle and aluminum industry models have equations similar to equations (1) through (4) of the steel model. (There is one extra factor input, nonproduction workers, but it is handled analogously.) Differences across industries arise primarily through the cost equation and output demand.

For motor vehicles, the differential of the cost function has the same form as it did for steel (equation 6), except that it incorporates the effects of changes in the prices of steel and aluminum:

$$\Delta \ln C = V_Q \Delta \ln Q - \Delta V_T + SS \Delta \ln P + SA \Delta \ln PA \qquad (11)$$

where SS = value share of steel in auto costs

SA = value share of aluminum in auto costs

PA = price of aluminum.

Equations describing output demand are similar in form to those for steel demand. The notation follows that for steel, except that the auto subscript (q) is used. The equations for automobiles are:

Import Demand[1]

$$\ln \frac{M_q}{Q_q} = C_2 + 1.166\ln \frac{P_q}{PM_q} + .347\ln \frac{M_q}{Q_{q\ -1}} \quad (12)$$

Motor Vehicle Demand

$$\ln A = C_3 - 1(\ln P_a) \quad (13)$$

Divisia Aggregation of Domestic Output and Imports

$$\ln A - \ln A(-1) = SM_q(\ln M_q - \ln M_q(-1)) + (1-SM\ )(\ln Q - \ln Q(-1)) \quad (14)$$

Divisia Index of Domestic Price [P] and Import Price (PM)

$$\ln P_a - \ln P_a(-1) = SM_q(\ln PM_q - \ln PM_q(-1)) + (1-SM_q)\ (\ln P - \ln P(-1)) \quad (15)$$

Share of Auto Imports

$$SM_q = \frac{PM_q M_q}{PM_q M_q + P_q Q_q} \quad (16)$$

Equation (12) indicates that auto demand is unit elastic (see [7, p. 44]). As in steel, these equations are differenced and combined with the differenced cost equation, the differenced input share equations, and any relevant identities to complete, the motor vehicle model.

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[1]The source of the import equation is Toder [7, p. 37, equation 2-2].

Aluminum

For aluminum, cost and share equations of the form of equations (1) through (4) are combined with an equation describing the demand for primary aluminum (QA) which is calculated from information in [1]. The demand for aluminum (in differenced form) is a function of the aluminum price and auto output[1] (Q) and is given by the following equation

$$\Delta \ln QA = -3\Delta \ln(PA) + .148\Delta \ln Q \quad (17)$$

The value, -3, is the elasticity of world demand for U.S. primary aluminum. This demand is total world demand less all supplies other than U.S. primary producers, i.e., it is an excess demand.[2] The elasticity of the excess demand curve can be calculated from the underlying supply and demand elasticities.

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[1] It is a function of other types of industrial output, but it is only necessary to consider autos here.

[2] The elasticity of total world demand is aggregated from individual elasticities of demand for the U.S., Japan, and the rest of the world (mostly Europe). The weights for aggregation are based on 1967 quantities, from [1]. The elasticity of world supply (less U.S. primary supply) is aggregated from supplies from the U.S. secondary aluminum industry, the rest-of-world secondary supply, and the rest-of-world primary supply.

The elasticity of aluminum demand with respect to auto output, .148, is shipments of aluminum to the auto industry divided by shipments to all industries.

Equations 1 to 17 form a unified model of the response of the aluminum steel and auto industries to technical change. The model can be used to determine effects on prices, quantities, input shares, and other variables.

Iron Ore

The model for iron ore is different from the others in several respects. First, we have no data on demand for capital inputs, so we can not estimate a complete translog model. Instead, we estimate only a labor demand equation see [3]. Second, there are external measures of technical change in iron ore mining and processing which perform better than a time trend in explaining labor demand. These direct measures are the fraction of ore pelletized and the fraction of ore dug by open pit methods (as opposed to underground methods).

Third, the iron ore model turns out to be independent of the model for the other industries. This is a consequence of: (1) an assumption that in the absence of pelletization, imports are the marginal form of supply, i.e., any change in steel output would be reflected in imports, (2) that the cost advantages of pellets in making steel are already incorporated in measured technical change in steel.

The effect of technical change on labor demand in iron ore is calculated from the labor demand equation. The hypothetical situation is with open-pit mining at its 1958 level and the complete absence of pelletization. The difference labor demand equation is:

$$\Delta \ln H = .61 \Delta \ln Q - 1.2 \Delta f$$

where H is total hours

Q is tonnage of usable ore

lnQ is the difference in lnQ, i.e., lnQ' - lnQ, where Q is actual and Q' is Q less pellet production

f is the 1958 fraction of crude ore from open pit mines less the actual level in each year

THE EFFECT ON EMPLOYMENT, COST, AND OUTPUT

The four-industry model in differentiated form is solved to estimate the difference in response to a difference in technology. As noted earlier, the interpretation of these differences is the difference between two situations at a given time: One in which technology is at its observed level, the other in which there is no technical change after the base period, in this case 1958.

The initial impact of an absence of change in technology would be to raise the cost of producing a given output. We estimate the effects in percentage form, as shown in table 1.

As indicated in the table, the absence of technical change would have raised costs slightly in the steel industry and substantially in motor vehicles and aluminum. These increases in costs would have led to higher prices and lower demand. The lower demand would reflect decreases in demand for the product and losses to other suppliers of the same or very similar products, namely, foreign producers and, in the case of aluminum, secondary producers.[1] The rise in price is reinforced by our estimated economies of scale; a rise in cost lowers demand, which, in turn, leads to a further decrease in demand due to the decreased scale.[2]

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[1]This is a partial equilibrium result in the sense that we are assuming that foreign producers would not have altered their behavior when there is no technical change in competing U.S. industries.

[2]In the model, the effects of scale and technology are considered simultaneously rather than sequentially, as in the discussion above.

TABLE 1

PERCENTAGE EFFECT ON COST OF PRODUCING OUTPUT WHEN TECHNICAL CHANGE IS ABSENT

Year	Steel	Motor Vehicles	Aluminum
1959	.3	-.4	-.37
1960	.7	-.4	1.0
1961	1.0	-.4	.9
1962	1.2	-.2	.1
1963	1.4	.5	.3
1964	1.8	1.3	1.5
1965	2.3	2.6	3.6
1966	2.7	4.2	6.4
1967	2.9	5.6	10.2
1968	3.0	7.1	13.9
1969	3.1	8.9	18.2
1970	3.2	10.6	24.1
1971	2.9	12.4	29.0
1972	2.4	14.7	32.9
1973	2.3	17.5	37.6
1974	2.0	20.5	43.5
1975	1.1	23.0	49.6
1976	.1	26.4	46.8

TABLE 2

PERCENTAGE EFFECTS ON OUTPUT

Year	Steel	Motor Vehicles	Aluminum
1959	.0	.6	2.6
1960	-.3	.5	-6.4
1961	-.4	.1	-5.7
1962	-.6	-.2	-.7
1963	-1.0	-1.1	-2.4
1964	-1.4	-2.4	-10.2
1965	-2.3	-3.9	-21.9
1966	-2.8	-5.6	-34.6
1967	-3.6	-8.0	-48.3
1968	-5.0	-10.4	-58.6
1969	-5.0	-12.2	-67.8
1970	-6.2	-16.0	-76.8
1971	-8.1	-18.7	-82.2
1972	-7.7	-19.4	-85.4
1973	-8.7	-21.0	-88.4
1974	-10.4	-24.7	-91.3
1975	-10.8	-31.0	-93.6
1976	-11.3	-31.2	-92.7

Tables 3 and 4 describe the percentage effect on price and employment due to an absence of technical change.

TABLE 3

PERCENTAGE EFFECTS ON PRICE

Year	Steel	Motor Vehicles	Aluminum
1959	.3	-.1	-.8
1960	.8	-.3	2.3
1961	1.1	-.1	2.0
1962	1.4	.2	.2
1963	1.7	1.1	.8
1964	2.2	2.4	3.5
1965	3.0	4.0	8.4
1966	3.7	5.7	14.9
1967	4.2	8.3	24.0
1968	4.9	10.9	33.4
1969	5.0	12.9	45.0
1970	5.6	17.4	61.4
1971	6.5	20.9	75.9
1972	6.2	21.5	87.9
1973	6.4	23.7	102.8
1974	7.2	28.7	122.8
1975	7.1	37.8	145.4
1976	6.7	39.4	135.3

The percentage effects on price and output would be modest for steel, high for motor vehicles and devastating for aluminum.

The effect of an absence of technical change on labor demand is a combination of two effects working in opposite directions. The drop in output reduces the demand for labor. On the other hand, we estimated that technical change is labor saving, so its absence would tend to increase the demand for labor, relative to other factors. The following table summarizes the effects on the demand for production workers (all workers for steel) due to an absence of technical change.

TABLE 4

PERCENTAGE EFFECTS ON LABOR DEMAND

Year	Steel	Motor Vehicles	Aluminum	Iron Ore
1959	.6	.1	2.5	-4.4
1960	1.1	.3	-3.9	-3.1
1961	1.6	.4	-2.8	-4.8
1962	1.9	.5	1.4	-11.5
1963	2.2	.6	.6	-4.6
1964	2.6	.7	-5.0	-7.2
1965	2.8	.8	-13.9	-11.7
1966	3.2	.9	-24.2	-15.0
1967	3.2	.8	-36.0	-16.6
1968	2.7	.7	-45.5	-21.1
1969	3.2	.6	-54.5	-33.1
1970	2.8	.2	-64.2	-35.8
1971	1.9	.0	-70.5	-41.2
1972	2.3	-.3	-74.4	-37.7
1973	1.8	-.3	-78.3	-43.4
1974	1.0	-1.0	-82.4	-44.2
1975	.7	-2.7	-85.9	-52.8
1976	.1	-1.7	-84.1	-51.9

For steel, in most years, labor demand would have been increased modestly by an absence of technical change. For motor vehicles, there would have been virtually no effect until about 1973, after which there would have been a modest decrease in employment. For aluminum and iron ore, employment would have been drastically reduced in the absence of technical change due to the large reduction in output. For iron ore, this decrease in output reflects the loss in output that would have occurred if the market presently served by domestic pellets had, instead, been filled by imports.

CONCLUSION

These results provide no support for the hypothesis that labor demand is sharply reduced by technical change. They provide some support for the opposite hypothesis, that technical change can ensure the continued health of an industry by keeping domestic industries competitive. This continued competitiveness prevents the adjustment costs to workers that characterize an industry in decline.

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