The Slowdown in Productivity Growth:
A Macroeconomic Model of Investment in
Human and Physical Capital with Energy Shocks

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Abstract

This paper focuses on supply side macroeconomics stressing an integration of investment in human and nonhuman capital and the contribution of both forms of investment to productivity growth, growth of supply, and hence to greater price stability. It develops a medium term macrodynamic model that, when subjected to energy shocks, generates a productivity slowdown similar to that observed in data which is presented for all of the O.E.C.D. nations. Investment in human capital is isolated within the national income accounts and integrated with macroeconomics, so that, as investment occurs, the new technology is embodied in the human and physical capital stock with faster positive effects on productivity and price stability.
The Slowdown in Productivity Growth: A Macroeconomic Model of Investment in Human and Physical Capital with Energy Shocks

Walter W. McMahon

This paper develops a macroeconomic model with interdependence between the real sector, monetary sector, prices, and productivity. Its objective is to analyze the potential for the embodiment of technology through human and physical capital formation as a means of maintaining productivity growth and greater price stability, (and hence international competitiveness) as the economies of this and other developed nations are subjected to repeated energy shocks.

Productivity growth is emphasized as a factor which helps to reduce inflationary pressures through a modified Phillips price equation both by increasing aggregate supply in relation to demand and by satisfying some expectations of growth in real wages and salaries. Productivity growth in turn depends significantly upon that investment in human and physical capital that embodies the latest technology in management and worker skills and machines bringing technical change to bear on production.

Energy shocks enter the model by increasing the inflation rate both directly and indirectly as the new inflationary expectations get built-in, and as restricted energy supplies adversely affect productivity. The monetary authorities then react eventually to high inflation rates (or alternatively to balance of payments and exchange rate problems) through a reaction function. The tighter monetary policy operates through the model to reduce capital formation, lower growth of GNP, productivity growth, employment, and inflation rates.
Part of the integration of human capital formation with a short to medium term macroeconomic model involves a cleaner separation of total investment, and in particular a cleaner investment in the National Income and Product Accounts. Part I of this paper therefore deals with that, extending work by R. Eisner (1979). It is a separable part of the paper and can be omitted by those less interested in the empirical definition of the variables and in the limits of National Income and Product Accounting. Part I however does develop two interesting points. First, some government expenditure and some household expenditure is investment, in the sense that it contributes to productivity later, whereas some is not, and only supports current consumption. The point is of significance when considering the mix of fiscal and monetary policies to be used in restraining aggregate demand when there is the desire to sustain medium term productivity growth. The second point suggests that when "Total Product" is computed as a supplement to the standard measure of GNP, the imputations for the returns to increased investment in education and air, water, and environmental improvements result in a growth from 1966 to 1973 that has not slowed down. 1973 of course coincides with the first of the worldwide energy shocks, and following these in 1973 and 1979 growth in all O.E.C.D. nations slowed down.

Part II is the first integration of investment in education and related human capital formation to my knowledge in either a short term or a medium term macroeconomic model. It would appear to be overdue because of the widespread concern about maintaining productivity growth and capital formation, particularly through forms of capital that are
less energy intensive to create and to use. There is probably also more of an empirical basis (e.g., in the research on earnings functions cited in Appendix A, and on productivity terms in the price equation) than there is for still longer run hypotheses that have been actively debated in recent years in pure macro economic theory.

The model in Part II can be condensed to three reduced form equations: An IS function with investment in both human and physical capital, an LM function that incorporates a partially endogenous reaction by the monetary authorities eventually restricting the supply of money in the effort to reduce inflation rates (or related balance of payments and exchange rate problems), and finally a PP price-productivity function that incorporates productivity growth as a function of total capital formation as well as the usual effects from unemployment and expectations. Part III considers solutions in comparative statics and for the short term dynamic impact multipliers. It is hoped that some of the implications may lead toward discussion of policy options that are less divisive than the growing tendency that has been noticed especially in Britain, the U.S., Sweden, and France for management-oriented and labor-oriented groups to heatedly blame one another when real incomes and productivity at best are constant.

I. The Integration of Human and Non-Human Capital in a System of Total Accounts: Has Total Growth Slowed Down?

Total product includes not only such standard imputations as those for the services of owner-occupied dwellings and for bank-money (clearing) services, but also imputations for the services of consumer investment goods consistent with a cleaner separation of consumption
and investment. Eisner's (1980) total investment account which is extended in Table 1 also includes another important step toward more clearly separating consumption from investment: the treatment of government investment in humans that yield returns later (e.g., education, health) as well as in buildings and roads, as investment, and government expenditure for items supporting consumption (e.g., welfare, social security expenditure, all in line 23) as part of total consumption rather than as capital formation. I have accepted Eisner's estimates for these amounts in Table 1 without change, including his treatment of national defense and police services as intermediate goods (noted in line 25) and his imputation for the non-market services of homemakers (line 12). Gross Domestic Product (GDP) as measured by the usual National Income and Product concepts is shown in the last column of Table 1. The total Personal Consumption Expenditures of $1,100.1 shown at the top, and components that add to the $1,702.2 totals permit some limited comparisons.

Two important items however must be added to obtain a concept of Total Product and of Total Productivity consistent with a full integration of human and non-human capital in the national accounts. They are imputations for environmental improvements (lines 19-22) and for the non-monetary returns during non-market hours from the increased education disseminated in the population, each of which will be considered in turn.

Environmental Improvements

The cleaner air in areas previously smog-bound and reduced pollution in some lakes and rivers contribute to greater consumption satisfactions
<table>
<thead>
<tr>
<th></th>
<th>Total Product Concept</th>
<th>NIA Concept*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private expenditures for non-durables &amp; services</td>
<td>579.8</td>
<td></td>
</tr>
<tr>
<td>(Net of 34.7 expenses related to work)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imputed rental value of consumer physical capital:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner-occupied housing</td>
<td>96.6</td>
<td></td>
</tr>
<tr>
<td>Durables</td>
<td>239.3</td>
<td></td>
</tr>
<tr>
<td>Semi-durables</td>
<td>106.0</td>
<td></td>
</tr>
<tr>
<td>Inventories</td>
<td>.7</td>
<td></td>
</tr>
<tr>
<td>Imputed rental value of human capital:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmarket returns to education</td>
<td>410.2</td>
<td></td>
</tr>
<tr>
<td>Nonmarket returns to better health</td>
<td>73.1</td>
<td></td>
</tr>
<tr>
<td>Services of home-makers</td>
<td>616.7</td>
<td></td>
</tr>
<tr>
<td>Net of time invested in repairs, etc.</td>
<td>-210.5</td>
<td></td>
</tr>
<tr>
<td>Expense account items of consumption</td>
<td>13.6</td>
<td></td>
</tr>
<tr>
<td>Imputed value of home-produced food, etc.</td>
<td>35.6</td>
<td></td>
</tr>
<tr>
<td>Transfers and subsidies allocated to consumption:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From business (media support, shoplifting)</td>
<td>22.2</td>
<td></td>
</tr>
<tr>
<td>From elemosynary institutions</td>
<td>42.0</td>
<td></td>
</tr>
<tr>
<td>Environmental Improvements (as final product)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of motor vehicle emission, air, and water pollution reduction</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>Cost of improving worker health &amp; safety</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Government consumption expenditures</td>
<td>97.6</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>97.6</td>
<td>97.6</td>
</tr>
<tr>
<td>Defense and police (reclassified intermediate)</td>
<td>0</td>
<td>94.9</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross private business investment</td>
<td>254.6</td>
<td>237.5</td>
</tr>
<tr>
<td>Fixed plant and equipment</td>
<td>162.2</td>
<td></td>
</tr>
<tr>
<td>Residential (excl. 00 housing)</td>
<td>10.4</td>
<td></td>
</tr>
<tr>
<td>Human capital formation: education</td>
<td>46.4</td>
<td></td>
</tr>
<tr>
<td>Human capital formation: health</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td>Research and development</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>Change in inventories</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>Consumer investment</td>
<td>567.7</td>
<td></td>
</tr>
<tr>
<td>Durables</td>
<td>156.6</td>
<td></td>
</tr>
<tr>
<td>Housing (0.0., non farm construction)</td>
<td>52.2</td>
<td>52.2</td>
</tr>
<tr>
<td>Semi-durables</td>
<td>84.8</td>
<td></td>
</tr>
<tr>
<td>Human capital formation: education</td>
<td>232.1</td>
<td></td>
</tr>
<tr>
<td>Human capital formation: health</td>
<td>35.5</td>
<td></td>
</tr>
<tr>
<td>Fixed investment by elemosynary inst.</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Change in inventories</td>
<td>.6</td>
<td></td>
</tr>
<tr>
<td>Government investment</td>
<td>317.8</td>
<td></td>
</tr>
<tr>
<td>Buildings, equipment, highways</td>
<td>59.6</td>
<td>34.2</td>
</tr>
<tr>
<td>Govt. Product Accumulated plus R&amp;D Subsidies</td>
<td>25.1</td>
<td></td>
</tr>
<tr>
<td>Human capital formation: education</td>
<td>185.7</td>
<td>84.9</td>
</tr>
<tr>
<td>Human capital formation: health</td>
<td>28.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Research and development</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td><strong>Net Foreign</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports</td>
<td>141.5</td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td>147.6</td>
<td></td>
</tr>
<tr>
<td>&quot;Total&quot; Gross National Product:</td>
<td>3,272.3</td>
<td>1,702.2</td>
</tr>
</tbody>
</table>

directly, as well as indirectly through better health. These improvements were insubstantial before passage of the Motor Vehicle Emission Control Act of 1965, the Water Quality Control Act of 1965 (amended in 1972), and the Air Quality Control Act of 1967 (amended in 1970). Although the cost of emission controls on trucks, factory waste discharge, and smokestacks has been substantial since that time, no imputation is normally included in consumption or total productivity for cleaner air, water or better health. Yet environmental improvement costs have been a major factor in the postulated decline of productivity as conventionally measured, as noted by E. Denison (1979, pp. 69-74). Table 1 includes a $13.2 billion imputation as part of Total Consumption (line 20-1) based on E. Denison's estimates of the factor cost of making these improvements (1979, pp. 71-2). Only business costs for emission and effluent controls are added since they are treated as intermediate product in the National Income and Product Accounts system, whereas expenditures by consumers and government are already included as final product.

Improved health as the result of the changes in the health and safety of employees is treated in an analogous fashion. Since only increments to the stock of human capital (and not the God-given stock of good health or the basic IQ) are all that is ever valued, this type of health and safety is treated as zero in 1966 (as are all other environmental improvements). By 1976, again based on E. Denison's incremental cost estimates, the imputation based on costs of the Federal Mine Safety Act of 1966 and Coal Mine Act of 1969 ($3.0 bil.), safety equipment on vehicles sold to business ($1.2 bil.), and the
Occupational Safety and Health Act of 1970 (OSHA, $1.3 bil.) totals $5.5 billion in Table 1 line 20 for improved worker health and safety. These estimates may be conservative in that they do not include the continuing benefits from past investment. But on the other hand, there has been a steadily increasing amount of expenditure under these acts, and making the imputations at factor cost has the advantage of basing them on hard data that cannot easily be manipulated.

Non-Market Returns to Human Capital

The monetary returns to education are included in the Compensation of Employees and hence reflected in Personal Consumption Expenditures in the National Income and Product measures (GDP in Table 1). It is reasonable that if human capital is productive in the labor market, it is only reasonable that as it is carried home, it is also productive of greater efficiencies there. Becker's concept of "full income" (1964, 1976), and the now widely used concept of household production, e.g., Schultz (1974) imply an imputation to final product for the services both of consumer durables and of education used to produce "commodities," or final satisfactions, during leisure time hours. R. Michael (1981) in reviewing the extensive research on measurement of the non-monetary benefits to education has estimated consumption-productivity at 60% of the labor market productivity close to an independently arrived at figure (McMahon, 1980, Table 4, p. 17). To obtain a conservative estimate of the non-market benefits, I therefore have estimated them at 50% (rather than 60%) of the market benefits, and these earnings in turn as 80% (rather than 95-100%) attributable to education. The result is non-market benefits of education of
$410.2 billion in Table 1, line 10 based on the 50% times 80% (the latter to remove the effects on earnings of IQ and factors other than education) times the Compensation of Employees. That this "alpha" of 80% is a conservative average of what recent careful research on this point is revealing to be the fraction of earnings attributable to education and learning is seen in the sixteen studies summarized in Appendix A. There over half the α coefficients are over .80, and the still more recent significant work such as that of Layard and Psacharopoulos (1974). Psacharopoulos (1975), and Griliches (1970, 1979) indicates an alpha of close to 1.0. So the 80% is a conservative estimate of the contribution of education to labor market productivity.

To impute nonmarket returns to investment in health, it is assumed that the returns during leisure-time hours after recovery are 0% of the foregone earnings originally invested and only 50% of the expenditure on hospitals, drugs, and physician care by households, government, and business, given that medical treatment is likely to be fully effective only part of the time. No imputation needs to be made for the monetary returns to investment in health, since monetary returns are already included in "Compensation of Employees."

The Growth of Total Product

The end result is that total product grew by 3.8% in 1966-76 expressed in constant dollars, well above the growth of 2.7% in the National Income and Product Account concept of real GNP, as shown in the last column in Table 2. This is due in part to the fact that the estimates discussed above of consumption returns to human capital and
Table 2

Growth of Total Product and the Slowdown in Growth of NIA-GNP

Average annual rates in constant (1972) dollars

<table>
<thead>
<tr>
<th></th>
<th>1956-66</th>
<th>1966-76</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Income and Product Account GNP</td>
<td>3.9%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Total Gross National Product (Table 1)</td>
<td>3.2%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Consumption Returns to Human Capital and Environmental Quality</td>
<td>4.3%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Investment in Human Capital</td>
<td>6.7%</td>
<td>5.6%</td>
</tr>
</tbody>
</table>

Source: Computed from the CEA Economic Report of the President, 1979, p. 184, and from R. Eisner (1980, pp. 9-12) for those components not discussed above.
environmental quality grew at 4.5%, and new investment in human capital grew at 5.6%, both well above the 2.7% increases in real NIA-GNP during this more recent decade.²

The second key point in Table 2 is that the growth of conventionally-measured National Income and Product Account real GNP slowed down from 3.9% to 2.7% in recent successive decades, whereas the growth of real Total Product held steady or slightly speeded up, from 3.2% to 3.8%. It can be noticed that although the rate of growth of investment in human capital by consumers and government especially was higher than the growth of NIA-GNP, and hence contributes to the higher growth of total product, the growth in human capital investment of all kinds has slowed down as fertility rates fell and the relative importance of defense needs again began to increase, and hence is not responsible for any increase in the rate of growth of total product since 1966.

The Effects of Energy Shocks

The slowdown in growth since 1973 however has been dramatic, by whatever measure. It is affecting all industrialized (OECD) nations, (and the LDC's as well) as is shown in the lower growth of GDP shown in the second line of Table 3 (and in Chart 3, p. 37). The slowdown began at a time that coincides with the first wave of OPEC price increases. It will be noticed that the countries that had the highest growth rates (toward the left in line 1) are also those that tend to have the highest rate of total capital formation (including investment in education and health) as a percent of GDP (line 4). The high-growth countries also tend to be the ones that have experienced the largest growth slowdown. The slowdown may be slightly overstated in Canada,
Table 3

Rates of Growth, The Slowdown Since 1973, and Some Causes

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>France</th>
<th>Germany</th>
<th>Canada</th>
<th>Sweden</th>
<th>Italy</th>
<th>U.S.</th>
<th>U.K.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth in Real GDP, 1966-73</td>
<td>9.5</td>
<td>4.9</td>
<td>3.9</td>
<td>3.8</td>
<td>3.2</td>
<td>5.2</td>
<td>2.9</td>
<td>2.5</td>
</tr>
<tr>
<td>(Per Capita, in %) 1974-79</td>
<td>1.9</td>
<td>2.3</td>
<td>2.1</td>
<td>2.0</td>
<td>.9</td>
<td>2.1</td>
<td>1.8</td>
<td>.7</td>
</tr>
<tr>
<td>Growth Slowdown (%-age Points) 1974-79</td>
<td>-7.6</td>
<td>-2.6</td>
<td>-1.8</td>
<td>-1.8</td>
<td>-2.3</td>
<td>-3.1</td>
<td>-1.1</td>
<td>-1.8</td>
</tr>
<tr>
<td>Feb-Mar-Apr 1980 Only:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Total Investment/GDP, '66-73</td>
<td>43.8</td>
<td>33.2</td>
<td>33.3</td>
<td>36.7</td>
<td>34.9</td>
<td>29.7</td>
<td>29.4</td>
<td>27.5</td>
</tr>
<tr>
<td>Human Cap. Only/GDP, '74-79</td>
<td>8.8</td>
<td>9.6</td>
<td>7.7</td>
<td>14.9</td>
<td>12.2</td>
<td>9.3</td>
<td>12.4</td>
<td>9.1</td>
</tr>
<tr>
<td>Phys. Cap. Only/GDP, '74-79</td>
<td>35.0</td>
<td>23.6</td>
<td>25.6</td>
<td>21.8</td>
<td>22.7</td>
<td>20.4</td>
<td>17.0</td>
<td>18.4</td>
</tr>
<tr>
<td>Annual Inflation Rate Jump Increase from '66-73 to '74-79</td>
<td>6.1</td>
<td>6.4</td>
<td>6.8</td>
<td>6.1</td>
<td>3.0**</td>
<td>16.0</td>
<td>3.9</td>
<td>13.7</td>
</tr>
<tr>
<td>Change in Phys. Invest/GDP '74-79</td>
<td>-3.1</td>
<td>-.9</td>
<td>-3.4</td>
<td>1.5</td>
<td>-.1</td>
<td>-.2</td>
<td>-.9</td>
<td>.7</td>
</tr>
<tr>
<td>Change in Human Invest/GDP '74-79</td>
<td>1.6</td>
<td>1.6</td>
<td>1.3</td>
<td>n.a.</td>
<td>1.2</td>
<td>-1.1</td>
<td>2.1</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*The beginning and end-point years, except for 1979, are peaks in cyclically-adjusted productivity.

**Understated since for domestic product only.
Sweden, and the United States since the percent of GNP invested in education each year is higher in these countries, which in turn yields non-monetary returns that are not included in the conventional measure of Gross Domestic Product.

Finally, the sharp increases in the inflation rate in almost all OECD nations is shown in line 7 of Table 3. These increases, which are larger in most nations than they are in the U.S., coincide with the successive increase in energy prices started by O.P.E.C. in 1973. The direct effects of oil price increases are measured more systematically within a wage-price-expectations model by McMahon and Goodman (1979).

II. A Macroeconomic Model of Total Investment

There is need to analyze this process within the context of a consistent model, since oil price increases are likely to continue to occur in the future. There has been widespread notice of the decline of physical capital formation in the industrialized world (see Table 3, line 8 above). Higher energy costs and tighter monetary policies following high inflation rates are less commonly built into macro models, but the accelerated slowdown in physical capital investment (Chart 1, p. 35), slower growth (Table 3, p. 11), and rising unemployment are the obvious outcome. It is significant that the growth in investment in education and health (Table 3, line 9 and Chart 2, p. 37) did not turn negative, probably because it is less responsive to high interest rates and rising energy costs than is other forms of investment. It is these facts that we seek to explain in the model that follows.
The three reduced form equations comprising the model, IS, LM, and PP or Price-Productivity, will first be developed from the underlying structural equations in order that the different behavior of investment in physical and human capital, and of the role of monetary policy in relation to prices and productivity can be clearly distinguished.

**Total Product Equilibrium**

At every instant in time, the following product-market (flow equilibrium) conditions consistent with Total Consumption (C) and Total Investment (I) as defined in Table 1 hold:

(1) \[ C = C[(1-t)Y, C_{-1}] \]
    \[ 0 < C_1 < 1, 0 < t < 1, C_2 > 0 \]

(2a,b) \[ I_P = I_P[K^* - (1-\delta)K_{-1}], \]
       \[ K^* = K^*(Y, r, i_{-1}) \]
    \[ 0 < I_P < 1, 0 < \delta < 1, K_1^* > 0, K_2^* > 0, K_3^* < 0 \]

(3) \[ I_H = I_H(Y, r) \]
    \[ I_{1H} > 0, I_{2H} < 0 \]

(4) \[ I = I_P + I_H + F \]

(5a,b) \[ Y = C + I, S = Y - C \]

**where:**

- \( C \) = real total consumption as defined in Table 1
- \( Y \) = real total output (full income)
- \( t \) = proportional tax rate, net of transfer payments
- \( I_P \) = real investment in physical capital
- \( I_H \) = real investment in human capital
- \( I \) = real total investment
$K^* = \text{desired real stocks of physical capital}$

$K = \text{actual real stocks of physical capital}$

$\delta = \text{rate of depreciation and obsolescence of physical capital}$

$r = \text{rate of return on physical capital investment relative to the rate of return on human capital investment}$

$i = \text{real rate of interest}$

$F = \text{net foreign investment (net exports)}$

$S = \text{total saving}$

Total investment in Eqs. (2-4) above includes investment in both human and non-human capital, $I_H$ and $I_P$, by government and by consumers, as well as by businesses. Consistent with this more refined view of investment, saving becomes total saving, which includes forced saving via taxation, household saving in durables, and household and government saving through human capital accumulation.

Consumption above is expressed as a function of total disposable income in real terms and of lagged consumption. Through a Koyck transformation this can be converted to permanent income or wealth, showing the representation of consumption habits via $C_{-1}$ to be isomorphic with the usual representation of permanent income as a geometrically distributed lag on past incomes. The tax function is represented by the net proportional tax rate, $t$, representing Federal, state, and local tax collections which taken together are roughly proportional.

Factors influencing the investment decisions in Eqs. (2) and (3) differ between physical and human capital investment, in that the stock-adjustment process including the response to excess capacity, $K_{-1}$, and the response to monetary policies and credit terms, $i_{-1}$, are
taken to be more pronounced for physical than for human capital investment. This is consistent with the greater cyclical volatility of physical capital investment shown in the data in lines 8 and 9 of Table 3 above, and with the fact that durable goods, fixed capital, and inventories tend to be financed more with bank credit than is human capital investment which is overwhelmingly financed out of parents' income and out of taxes. Both forms of investment are assumed to be influenced by the relative rate of return, r, which has been higher for human capital since 1900, consistent with the higher rate of accumulation of human capital.

When Equations (1-5) are solved simultaneously by substitution into Eq. (5), the IS function representing real product equilibrium is obtained:

\[ Y = IS(C_{-1}, t^*, (1-\delta)K_{-1}, r, i_{-1}) \]

If the system is linear, \[ \frac{\delta Y}{\delta i_{-1}} = \frac{K_3 L_0}{1-c(t-r) - K_1 L_1 - I_{1H}} < 0 \]

and the IS curve will have the usual downward slope if we also require that the total marginal propensity to spend contained in the denominator is less than unity (i.e., \( c(t-r) + K_1 L_1 + I_{1H} < 1 \)), since the numerator is negative from the self-explanatory restrictions shown above.

The demand for money function is perfectly standard except for the fact that the demand for money shifts inversely in relation to changes in the anticipated rate of inflation as is consistent with Keynes' (1936) original statements on this point as well as with Friedman (1959) and others. Together with the supply of money, the result is
an LM function representing equilibrium in the money markets which are assumed to adjust quickly:

\[ \frac{M^d}{P} = L(Y, i, \pi, M_{-1}), \]
\[ L_1 > 0; L_2 < 0; L_3 < 0; 0 < L_4 < 1 \]

\[ \frac{M^s}{P_{-1}(1+p)} = M((p - p^*), M_{-1}) \]
\[ -1 < \frac{\partial M^s}{\partial p} < 0; M_2 = 1 \]

\[ M^d = M^s = M \]

Variables not already defined following Eq. (5) are:

- \( M \) = the nominal stock of money, with \( d \) = demand and \( s \) = supply
- \( P \) = the price level
- \( \pi \) = the expected rate of inflation
- \( M_{-1} \) = the nominal rate of growth at the end of the preceding period,
- \( p \) = the rate of price inflation \( \equiv \frac{P - P_{-1}}{P_{-1}} \)
- \( p^* \) = the politically tolerable rate of price inflation (which may differ somewhat among countries, and at different points in time)

In the supply of money function, the monetary authorities are assumed to adjust the money supply growth by adopting a relatively more restrictive policy when the inflation rate \( (p) \) becomes too high in relation to acceptable levels \( (p^*) \). They are assumed to respond primarily ex post after the announcements of higher unexpected inflation rates, although the ultimate objective of course is to control the rates of inflation expected in the future. This kind of a reaction function seeks to capture the tightening of monetary policy almost
countries, and of fiscal policies in some in response to the continued strong inflationary pressures in 1974 and again in 1980 leading to increases in nominal interest rates. It responds to oil price pressure as would the alternative use of a monetary policy response to exchange rate fluctuations or balance of payment disequilibrium, which as J. Melitz and H. Steryniak (1979) point out are well established econometrically. However the latter emphasize the induced adjustments among countries, whereas the model stresses the simultaneous shock to all countries. The condition that \(-1 < \partial M^S/\partial p < 0\) in Eq. (8) does imply a partial response to the shocks in the short run due to the concern about avoiding too much unemployment. But the price term implicitly allows for some monetary response to growth needs as well as some tightening when inflation rates worsen.

In order to focus on the current rate of inflation, \(p\), rather than the current price level, \(P\), it is convenient to redefine \(P\) as:

\[
P = P_{-1} (1+p).
\]

Substituting Eqs. (6, 7, and 9) into (8) yields the LM function representing instantaneous money-market equilibrium:

\[
(11) \quad i = LM(M_{-1}, \pi, p-p^*, \gamma)
\]

which can be rearranged and solved instead for the quantity of money (instead of \(i\)) if one prefers. However this is a conventional LM function that does slope upward given the prior restrictions (i.e., \(\partial Y/\partial i = -L_1/L_2 > 0\) given that \(L_2 < 0\) and \(L_3 > 0\) above). Monetarists and Neo-Keynesians are agreed that changes in the money supply only
affect the real sector after a lag of 6-9 months at least, so this entire function must be subject to a time delay (or to a distributed lag) before it is substituted into the LM function thereby allowing dynamic impact multipliers to be calculated. It is these dynamic impact multipliers that are of most practical interest as the money supply and later income respond to policies attempting to maintain employment and yet to control inflation once it becomes excessive since it is reasonable to assume that there will be further changes in policy before the equilibrium multipliers have had time to fully work themselves out.

The system is underdetermined even if p*, and t* are treated as policy-determined parameters, C_2, K_2 and M_2 as pre-determined initial conditions, and r and n as given. This is essentially because there are only two equations, (6) and (11), to determine Y, i, and p. To close the model, Keynes treated the wage rate, and hence prices which were set by firms proportional to marginal costs, as given allowing the model to be solved for Y and i. The monetarists on the other hand take Y exogenously given at the full employment level, with p and i determined endogenously by changes in the money supply. We take an intermediate position, with the rate of increase in prices p and hence P since P = P_{-1}(1+p) determined endogenously by a modified Phillips price equation containing expectations. But it also contains the effects of slower productivity growth and the effect of energy price increases, both of which get built-in to price expectations.
Aggregate Supply, Prices, and Productivity

The structure of the wage-price interaction process will be considered first, leading to the reduced form price equation. Since prices are a function of the growth of aggregate supply (or potential output) and of productivity, these latter elements will then become part of the full specification of the Price-Productivity (PP) sector. This leads toward a Keynesian-Monetarist-Neoclassical synthesis: Keynesian in that output is not always at full employment and prices and real wages are not fully flexible downward; Monetarist in that increases in the money supply increase prices through demand-pull forces when not offset by aggregate supply or productivity changes; and Neoclassical in that productivity and aggregate supply are affected in the intermediate (4-5 year) period through a Cobb-Douglas type production process.

Prices. The price and wage formation processes developed in Eqs. (12) and (13) below are relatively standard specifications. Attention however is drawn to the effect of crude-oil price increases $p_o$, tested by D. Goodman and W. McMahon (1979), and of productivity changes tested by Yekstein and Girola (1978). These effects accommodate the slowdown in productivity growth developed further by Norsworthy, Harper, and Kurge (1979), Gordon (1979), and others.

\[ p = p[(Y^* - Y)^{-1}, w, y-n, p_o]^4 \]

\[ w = w(u^{-1}, \pi)^5 \]

where: $p_1 = 0$ until $Y < Y^*$, $0 < p_2 < 1$, $p_3 < 0$, $p_4 > 0$

$w_1 > 0$, $w_2 > 0$, $w_3 > 0$
\[ Y^* = \text{potential (i.e., full employment) total output} \]
\[ w = \text{percent rate of increase in wages} \]
\[ y-n = \text{percent rate of increase in productivity (i.e., in output per worker)} \]
\[ p_o = \text{percent rate of increase in the price of crude oil} \]
\[ U = \text{percent unemployed} \]
\[ \pi = \text{expected rate of inflation} \]

This wage-price interaction process allows demand-pull forces to operate as \( Y \) approaches \( Y^* \) and unemployment decreases toward the natural rate. However, a larger products-gap as recession sets in is assumed to have an insignificant effect on product price increases due to the offsetting effect of cyclical productivity changes, (i.e., \( p_c = 0 \) consistent with most econometric findings). As the wage equation is substituted into the price equation for \( w \) above, the desired effects on the inflation rate must await the effects of rising unemployment since \( w_1 > 0 \) on the rate of increase in money wage costs.

To simplify this interaction process into a reduced form price equation, it is convenient to use Okun's law to combine the unemployment gap with the products gap:

\[(14) \quad Y^* - Y = \delta_0 U, \quad \delta_0 = 3 \]

and to assume that inflationary expectations are generated by an adaptive process:

\[(15) \quad \dot{\pi} = \gamma(p - \pi), \quad 0 < \gamma < 1. \]
This endogenization of expectations (to be discussed further as part of the dynamics of the system below) can be integrated so that the expected rate of inflation is seen to be a weighted average of past rates of inflation:

$$\pi = \gamma \int_0^t p_T e^{-\gamma(t-\tau)} d\tau$$

This exponentially weighted average of past rates of inflation builds the adverse effects of past increases in crude oil prices and past declines in productivity growth into the system.

Reflecting these demand-pull, cost-push, and productivity-supply deterrent effects, the reduced form price equation is:

$$p = p_w[(Y^* - Y)^{-1}, p_T, y - n, p_o], \quad t = -\infty, \ldots, t$$

There would be a delayed price response to increases in aggregate demand when output is at less than full employment, and hence some response in the form of quantity adjustments to fiscal or monetary policies. This is because as demand recovers, the remaining slack retards the rate of price and wage increases, with productivity increases allowing both profits and real wages to grow (i.e., \( p_1 = 0 \), \( p_2 = 1 \), and \( p_3 < 0 \)), at least insofar as these desirable effects are not counterbalanced by unstable expectations (\( \gamma > 1 \)) and/or further U.P.E.C. price increases.

In the reverse direction, as output declines, inflation rates do not subside as slack first appears. This is because of the adverse effects of cyclical declines in productivity (\( p_3 < 0 \)) and the persistence of inflationary expectations. The positive effect on inflation...
rates would only be felt (short of drastic depression) as the decline is arrested so that productivity does not continue to decline while the slack is maintained.

**Growth of Productivity.** Since we are concerned here with effects that can be felt within an intermediate 4-5 year period, the rates of human and physical capital formation that embody the new technical progress have effects on productivity. Physical capital investments are necessary to modernize the best practice plants, and capital formation is necessary to improve the average practice within each industry which is what is crucial to determining international competitiveness. Similarly, some human capital investment could have a short-term payoff. For example, in France there is a 1% profits tax that is forgiven to those firms that invest to improve the knowledge and skills of their workers. Also two year U.S. community college training programs for workers who might otherwise be unskilled and unemployable sometimes can raise productivity quickly. Other examples of human capital formation that have the potential of affecting productivity within a shorter 3-4 year time span might include the two year training of computer technicians in Community Colleges (e.g., for computerized sales processes, medical diagnoses, library circulation systems, etc.), good two-year MBA programs, and some short courses to update the skills of employees. Physical capital formation has sometimes increased productivity in the short term as when tractors replaced horses freeing grazing land, and hybrids, genetics, and weed control technology further increased agricultural productivity.
Output therefore in the medium term is determined in accord with a production function within which technical progress is brought to bear on production through investment in education that embodies the newer knowledge in workers and managers, and physical investment that embodies the new technology in the newer machines. It is assumed to be of Cobb-Douglas form with Solow-neutral human and physical capital augmenting technical progress:

\[ Y_t = A \left( e^{aU_1H_1} \right)^{Y_1} \left( e^{aU_2K_1} \right)^{Y_2} (U3)^{Y_3} O^{Y_4} \]

where:
- \( a \) = embodied technical progress embodied at a given proportional rate through investment in human and physical capital
- \( H \) = human capital,
- \( K \) = total physical capital,
- \( N \) = the labor force (total potential man hours of raw labor independent of any improvement through investment),
- \( O \) = oil and energy supplies (allowing for import shocks),
- \( U_1, U_2, U_3 \) = utilization rates of human capital, physical capital, and raw labor, where \( U_3 = 1 - U \), and \( U \) = the unemployment rate.

Since equation (18) applies to each vintage \( t \), where \( t = t, ..., w \), it is possible to sum each variable over vintages so that the production function determines total aggregate output. Underutilization of human and physical capital appear explicitly since both have an effect on productivity. This underutilization is particularly severe, and has the most negative effects on productivity growth during periods of
cyclical decline when labor is laid off, but human and physical capital necessary to the future operation of firms remain "employed" but underutilized. Longer run underutilization due to reduced worker incentives or other factors of course would also have adverse effects on productivity.

In the case where there is full utilization and full employment, $U_1 = U_2 = U_3 = 1$ and this production function determines potential output, $Y^*$. Together with actual output which is jointly determined by the demand-oriented IS-LM sides, the gap in the products market which is one determinant of the rate of increase in prices (Eq. 17) is determined.

Next, the main determinants of productivity growth can be derived from this production function for substitution into the price equation (17). To do this first take the logarithms of the production function (18), which is then totally differentiated with respect to time to obtain the percentage rates of change over time of each variable (represented by lower case letters, as for example $y = \Delta Y/\Delta t(1/Y)$, and similarly for all the inputs. The result is:

\[ y = \gamma_1(a_h+u_1) + \gamma_2(a_k+u_2) + \gamma_3n + \gamma_4o \]

This indicates that increments to the stock of human capital such as appropriate advanced education of the management and workers, refresher courses that update skills, and new learning through experiences on the job that embody the new technology, as well as physical capital formation that also serves to embody the new technology together lead to the growth of potential output.
However some older vintages of capital machinery and human capital without the newer skills can stand idle and underutilized while the newer machines and human capital embodying the newer technology have lower cost per unit of output and therefore can remain employed. Examples occur in the closing of the older, less efficient mines in the U.S. and British coal industry, the redundancy of the older and less efficient plants in the French, British, and U.S. steel industry, the lag of average productivity in Swedish industry behind that in the newer best-practice plants, and even the merging of smaller farms and redundancy of unskilled agricultural labor in the agriculture industry not only in the developed countries but also in the LDC's. In all of these cases, all human and physical capital is not fully utilized because of partial obsolescence. So for this reason, as well as where there is reported unemployment of raw labor, output growth lags below its potential \((y < y^*)\).

To obtain the growth of production per worker from equation (19), it will simplify the notation to redefine \(n\) as the percentage rate of growth in the number of workers employed. Then if it is assumed that the production function has the common neoclassical property of positive but diminishing marginal returns to each factor, as well as constant returns to scale, i.e.:

\[
\begin{align*}
F_i > 0, F_{ij} < 0, \gamma_3 = 1 - \gamma_1 - \gamma_2 - \gamma_4
\end{align*}
\]

the latter expression may be substituted for \(\gamma_3\) in Eq. (19) and \(n\) may be subtracted from both sides to obtain:

\[
\begin{align*}
(y - n) &= \gamma_1(a + h + u_1 - n) + \gamma_2(a + k + u_2 - n) + \gamma_4(\theta - n) \quad u \neq 0
\end{align*}
\]
Productivity per worker \((y - n)\) is raised above through increased investment in the education of each worker which embodies the new technology \((a + h + u_2 - n)\) and through increased amounts of physical capital per worker which embody newer design \((a + k + u_2 - n)\).

Increased utilization \((\text{with } u_1 = u_2 < 0)\) would also have a positive effect. It could be related to incentives but is related here to cyclical underutilization when there is slack demand. In the reverse direction, the decline in productivity growth since 1973 is caused within the context of the logic of equation (21) in part by the restriction in oil supplies \((o < 0)\) augmented by curtailment of physical and human capital formation due to restrictive policies and to further accelerator effects on investment.

This set of interdependent effects is consistent with E. Denison's finding that there has been a sharp decline in the contribution of the residual to the growth rate. His estimate is that the contribution of the residual to the adjusted growth rate has declined from a positive 1.4 percentage points per year prior to 1973 to a negative -.7 percentage points since that time (1979, p. 2). The combined impact of underutilization during this period \((\text{with } u > 0 \text{ in much of 1974 and 1975, as well as more recently})\), restricted growth of energy supplies \((o < 0)\), with low capital formation per worker may be sufficient. We do not explore such issues as the deterioration of the work ethic, preferring to confine attention to factors that are quantified within a system of total product accounts. The "work ethic" appears also to have been a major issue during the industrial revolution, and although much discussed, is also much more nebulous. We also ignore the issue of whether
the government sector is too large or not, and the effects of related shifts between public and private employment, with its closer relation to politics and political interest groups. The investment incentives stressed in equations (2) and (3) above have more to do with the higher rate of return or lower unit labor costs from embodiment of the newer technologies.

Finally, human capital formation has some indirect effects on productivity that are not endogenous to this model, but that should be noted. First, there is evidence stressed by T. W. Schultz in his Nobel Prize lecture for example (1979) that increasing education of women reduces fertility rates. This effect on population growth, reducing $n$ in Eq. (21) is of great importance to the future of the LDC's. There are also indirect effects of human capital formation on total capital formation (e.g., via longevity, and via saving rates), and it is known that education is positively correlated in the DC's with the number of productive years before retirement, the number of hours worked per week, and with female labor force participation rates.

The Price-Productivity Function. These determinants of the growth of productivity in Eq. (21), together with $(1 + y*)Y^*_{-1}$, can now be substituted for $(y - n)$ and for $Y^*$ respectively in the reduced form price equation (17) to obtain:

$$(22) \quad p = PP[(Y^* - Y)^{-1}, p_t, c, \gamma_1(a + h - n) + \gamma_2(a + k - n) + \gamma_4(o - n) - u, p_o]$$

This price-productivity function can be simplified. First, the rate of change in energy supplies, $c$, can be replaced by the rate of change in their price, $p_o$, using Eq. (23), and then the terms collected in Eq. (24).
This assumes that there are substitutes in consumption and in production for some energy as its price rises, as illustrated by the demand curve DD in Figure 1. Then as energy supplies are restricted ($o < 0$ in Figure 1), energy prices rise ($p_o > 0$), so that in the short to medium term periods under discussion, the price term will pick up the quantity restriction as well:

$$\frac{\partial Q}{\partial p} = o(p_o), \quad \frac{\partial Q}{\partial p} < 0$$

The simpler PP function is:

$$p = PP[Y^* - Y; a + h - n, -u; p_o, p_t]$$

The three groups of terms representing aggregate supply in relation to effective demand, productivity growth, and energy shocks, interrelate prices and productivity complete the IS-LM-PP model of the economic system.

A simpler graphical representation of the model and exploration of its comparative static and short term dynamic properties follow.

III. Capital Formation and Price Stability

The model is summarized in the simplified forms of the IS-LM-PP functions shown below, and in Figure 2 illustrating this result.

It seems likely that energy shocks will continue indefinitely, especially in light of the underlying political instability in the Middle Eastern nations. Therefore in discussion of the model, it will be assumed that substantial energy shocks continue, so that it is meaningful to trace the possibilities for sustaining productivity growth. One possibility is to choose forms of investment that contribute the
most to the growth of total productivity (e.g., yield the higher total rates return), while simultaneously requiring less energy for their production and use. It will be suggested that one type of investment that meets these criteria is investment in those types of education that yield high total rates of return. A second suggestion involves shifting somewhat from the high physical capital per man industries toward the high technology, high human capital per man industries in the output mix, and in the export mix.

The IS-LM-PP Model

The model summarized in equations (25), (26) and (27) below is the same as that developed above in equations (6), (11), and (24) with two additional modest simplifications. First, it is assumed that the rate of depreciation affecting the IS function is zero (i.e., $\delta = 0$). This is not only consistent with the focus on gross investment in equations (2) and (3) and total gross national product in Table 1, but also with the putty-putty nature of the vintage model that has now been developed. That is, technical change embodied in the most recently produced units of human and physical capital makes them more profitable to use, while the older vintages into disuse and become part of the unutilized capacity that just fades away. There is not only substitution between capital and labor as the new units of human and physical capital are produced, but also in the Cobb-Douglas production function there is substitution between them after installation. Therefore it becomes possible to allocate less raw labor to the use of units of human and physical capital as they get older, so that even with the assumption of no depreciation or scrapping ($\delta = 0$) these units fall into disuse and
simply fade away, passing into the domain of excess and underutilized human and physical capital capacity. New investment can continue since capital in this model is non-homogeneous, and the newly-produced units embodying the newest technology carry a higher rate of return.

A second simplification is possible by substituting past prices, $p_t$ as given by equation (16), for the expected rate of inflation in the demand for money and hence in the LM function. So simplified, the IS-LM-PP model is:

\begin{align*}
(25) \quad Y &= IS(i_{t-1} \mid C_{t-1}, K_{t-1}, r, t^*) \\
(26) \quad i &= LM(Y, p \mid M_{t-1}, p_t, p^*) \\
(27) \quad p &= PP(Y^* - Y, y-n \mid p_t, p_o)
\end{align*}

These three sectors are illustrated below in Figure 2, treating for this purpose the terms to the right of the vertical lines as parameters. This can be done for purposes of short-run analysis (but not $y-n$ which is soon to be replaced with $I_H, I_P,$ and $u$) since they are either stocks that change relatively slowly ($H, K, K_{t-1}, M_{t-1},$ and $C_{t-1}$ regarded as habit-wealth stocks), are predetermined ($p_t, p_o$), or are policy parameters ($t^*, p^*$).

**Stagflation**

The main causes of the slowdown in growth and stagflation using the IS-LM-PP model may now be illustrated using Figure 2. The empirical relevance of the PP function in the U.S., U.K., and France under the conditions of some unemployment above the natural rate is shown in Figures 3 and 4.
Figure 2. IS-LM-PP Adjustments to Higher Inflation Rates
(U < Natural Rate)
First, with oil price shocks rising the inflation rate directly
and through expectations from 0 to 1, shifting the PP function upward
to P'P', the intolerably high inflation rates lead to more restric-
tive monetary policies, shifting the LM curve to the left. This slows
investment and the new equilibrium income level is at Y_2 slowing the
rate of growth of income (e.g., \( \frac{Y_2 - Y}{Y_0} = y < 0 \)). This slows the rate
of productivity growth, or (y-n) in Figure 2 because:

1. Lowered investment slows the rate of embodiment of the new
technology in the human and physical capital stocks. As these
become progressively more out of date and hence relatively
less productive, there are adverse price effects along PP, to
point 2 in Figure 2.

2. Changes in the level of unemployment lead to lower utilization
rates for white-collar human capital and for physical capital
goods. These contribute to cyclically lower rates of growth
of productivity, with adverse price effects included in the
movement to point 2 along PP in Figure 2.

The new equilibrium (at Y_1) is one of slower growth and higher infla-
tion. Once the trough is reached, u = 0, the adverse cyclical impact
of increasing underutilization on productivity growth is arrested.
Then as the level of unemployment remains high, the price-productivity
function shift downward in accord with the traditional Phillips curve
effect as shown in Figure 2.

Expansion

Increased investment in human capital and physical capital, either
at less than full employment or as a percent of GNP, that embodies new
product and process technologies would increase total productivity from say, 2, along the PP function to point 1. There is also a cyclical effect increasing productivity further as the result of increased utilization. The empirical relevance of this PP function in the 1970's is illustrated in Figure 3 for the U.S., U.K., and France. (See page 35)

Real wages can rise as the result of the increased productivity without commensurate increases in price. In the low productivity growth countries, either real wages must be held constant resulting in great labor unrest, or all real wage increases merely spill over into increased prices. That is, the productivity increment is available to diffuse some of the pressure from price expectations on both wages and prices.

Dynamic Impact Multipliers

To go beyond the comparative static analysis presented above, it may be useful to repeat the basic IS-LM-PP model before considering the medium term (3-4 year) dynamic impact multipliers. It is:

(28) \[ Y = IS(i_{-1}, C_{-1}, K_{-1}, r, r^*) \]

(29) \[ i = LM(Y, p_{M-1}, P_r, P^*) \]
\( p = PP(Y^* - Y, y-n|p_T, p_o) \)

To analyze the impact of energy price increases on investment and output, the following dynamic impact multipliers showing the impact after 2-4 years are desired:

\[
\frac{\partial I}{\partial p_o}, \quad \frac{\partial I_H}{\partial p_o}, \quad \frac{\partial (1+y)Y_{-1}}{\partial p_o}
\]

The decline in investment in physical capital following the OPEC price increases, other inflationary pressures, and tightened monetary policies in late 1973 and again in 1979-80 are illustrated in Chart 1. The slowed growth rate of real GNP, which declined precipitously in the first half of 1980 was shown in Table 3. The growth of investment in human capital is slowed by this slower growth of real GNP, but probably since it is not affected as directly by credit terms and monetary policy, it does not decline sharply as a percent of GNP as is illustrated in Chart 2.

The effects of policies designed to increase productivity as a means of restraining inflation and maintaining growth under conditions of repeated energy shocks are also of interest. To analyze these, the following dynamic multipliers are needed:

\[
\frac{\partial (y-n)}{\partial (h+a-n)} = 7.27 \text{ (See the slope in Figure 5 where } h = \text{ percent change in schooling per capita.)}
\]

\[
\frac{\partial (y-n)}{\partial (k+a-n)} = 0.51 \text{ (See the slope in Figure 6, where } k = \text{ percent change in business capital per worker.)}
\]

The combined effect of total investment in human and non-hum capital is illustrated in Figure 7. The weights given to human (0.46) and
physical capital formation (.42) are calculated from an estimate of the relative contribution of each to the growth of National Income Per Person Employed from 1948 through 1973 by E. Denison (1979, p. 2). The combined effect is estimated as a function of the growth of total investment which has been adjusted as shown for a constant level of utilization, needed since utilization rates were distinctly lower throughout this period in the U.S., Italy and Canada:

\[
\frac{\partial(y-n)}{\partial(0.46h + 0.42k)} = 3.61, \text{ an estimate of the effect of total investment.}
\]

A joint solution of the IS-LM-PP model above will produce dynamic multipliers that allow in a precise fashion for the general equilibrium interdependencies.

**The Price-Productivity Relation in the 1970's**

*Figure 3. Over Time; 1973-1979*
Decline in Physical Capital Formation Since 1973

Chart /
Fixed Investment as a percent of GNP (compare changes rather than levels)*

United States

Japan

Italy*

Germany

France*

United Kingdom*

GDP

*Levels are not adjusted for differences in National Accounts Treatment of Investment by Government.
Slowdown of Growth in Human Capital Formation
Since 1972

Chart 2

(Total investment in education (public + private investment) as a percent of GDP)

- United States
  - '73
  - '65
- Japan
  - '78
  - '65
- Italy
  - '73
  - '65
- Germany
  - '73
  - '65
- France
  - '73
  - '65
- United Kingdom
  - '73
  - '65
Sources of Productivity Growth 1963-1973

Figure 5. Human Capital Formation and Productivity

Figure 6. Physical Capital Formation and Productivity

Figure 7. Total Capital Formation and Productivity

- Change in Educational Attainment of the Population Aged 25-69.
- Change in Physical (Business) Capital per Worker.

*UK, Norway, Sweden, France, Germany, Italy, Japan*

*Increase in Human Capital per Man (K74-K80)*

*Increase in Physical Capital per Man (K74-K80)*

*Increase in Total Capital per Man (K74-K80) Adjusted for Rate of Utilization of Each*
References


Appendix A. Proportion of earnings differentials due to education relative to ability and other factors (U.S.A.)*

<table>
<thead>
<tr>
<th>Level of schooling</th>
<th>&quot;OTHER&quot; (Adjustment reference)</th>
<th>Education</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher education</td>
<td>Ability + other</td>
<td>.67</td>
<td>Denison (1964)</td>
</tr>
<tr>
<td>Primary</td>
<td>Ability + other</td>
<td>.88</td>
<td>Denison (1974)a</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td>.88</td>
<td></td>
</tr>
<tr>
<td>B.A.</td>
<td></td>
<td>.88</td>
<td></td>
</tr>
<tr>
<td>One year graduate study</td>
<td></td>
<td>.48</td>
<td></td>
</tr>
<tr>
<td>Higher</td>
<td>Ability</td>
<td>.80b</td>
<td>Becker (1964)</td>
</tr>
<tr>
<td>Higher</td>
<td>Ability + other</td>
<td>.65c</td>
<td></td>
</tr>
<tr>
<td>Higher</td>
<td>Ability + other</td>
<td>.74d</td>
<td></td>
</tr>
<tr>
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<td></td>
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<td></td>
<td>.52d</td>
<td></td>
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<tr>
<td>Secondary</td>
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<tr>
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<td>.88</td>
<td>David (1963)f</td>
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<tr>
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<td>Ability</td>
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<td>Hansen, Weisbrod</td>
</tr>
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<td>and Scanlon (1970)</td>
</tr>
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<td>Mostly ability only</td>
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<td>Ability</td>
<td>.81</td>
<td>Hauser et. al. (1971)</td>
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Notes:  
a. Based on Table 3.1 above.  
b. Using the Bell data or the Wolfe and Smith data and class rank as a proxy for ability.  
c. Using the Wolfe and Smith data.  
d. Using the Morgan and David results: averages for ages 18-34 and 35-74.  
e. Based on Gorseine; not corrected for underreporting of earnings.  
f. Refers to the ages 35-44.  
g. Using the NBER-TH sample.  
h. Using the Rogers sample.  
i. Overall average of the alphas implied in Gintis.
Footnotes

*The author is Professor of Economics at the University of Illinois in Urbana-Champaign. He would like to express appreciation to members of the Department of Economics at the London School of Economics, the Research Unit at I.N.S.E.E. in Paris and the Industrial Institute for Economic and Social Research in Stockholm for their useful comments as this manuscript was being written. Special thanks are due George Psacharopoulos, Richard Layard, Kieth Hartley, John Carlson, Pascal Mazodier, Jacques Melitz, Bo Carlsson, Bertil Holmlund, and Gunnar Eliasson for helpful comments. None have responsibility for the end result, which rests solely with the author.

1 Robert Eisner's totals for investment in education and health are allocated 50% to households, 40% to government, and 10% to business. His total for R&D is allocated 50% to business and 50% to government. Total Product less lines 10, 11, and 19-22 plus $182 bil. of revaluations due to capital gains equals Eisner's TISA Gross National Product.

2 For deflation, the implicit Personal Consumption Expenditure Deflator was used for nonmarket returns to human capital, environmental improvements, and all investment in human capital. Much of the latter is usually included in Personal Consumption Expenditures. More specific deflation best awaits R. Eisner's NSF-supported work now underway.

3 The relative homogeneity in the cyclical behavior of investment in consumer durables and in producer durables is shown graphically analyzed in W. McMahon (1957), which contrasts with the econometric determinants of investment in human capital developed in W. McMahon (1974, Chs. 3 and 4).

4 Eckstein and Girola's (1978, p. 333, Eq. A4) estimates of the price equation for the U.S., 1891-1977, for example that are consistent with this specification and set of restrictions (t-statistics in parentheses) is:

\[ p = 0.31 \frac{w}{y-n} + 0.60 p - 6.62 \phi^{*} + u \]
\[ R^2 = 0.89 \]
\[ DW = 1.80 \]

When the inverse of the unemployment rate was inserted as a proxy for demand pressure, it was offset by short term productivity changes over the cycle and insignificant, a common finding is macro price equations. When the unit labor cost coefficient above of .31 was constrained to be .6 consistent with Cobb-Douglas production function and input-output evidence, the coefficient for raw material prices \( p^m \) (which includes oil) becomes .50 with \( t = 14.51 \). \( \phi^{*} = \) Nixon's wage-price guideline policy.
Eckstein and Girola's (1978, p. 333, Eq. A2) estimate for example of the wage equation for 1891-1977 consistent with this specification and these restrictions, with t-statistics shown, is:

\[ w = 6.98 V^{-1} + 1.17 p - 0.23 (p_{-1} + p_{-2}) + 0.32 (y-n) + u \]
\[ (2.66) \quad (13.86) \quad (-2.72) \quad (2.00) \]
\[ R^2 = 0.80, \quad DW = 2.28 \]

Here unemployment is not corrected for labor force mix, which is common in postwar regressions and the distributed lag on past price changes serves as the usual proxy for price expectations.

Econometric estimates of a price equation containing productivity growth and crude oil prices are offered by D. Goodman and W. McMahon (1979, p. 38, Eq. 4):

\[ p = 0.76 (Y^* - Y)^{-1} + 1.06 (w - (y-n)) + 0.18 (w - \bar{w}) - 0.06 ((y-n) - (y-n)) \]
\[ (1.92) \quad (7.19) \quad (1.32) \quad (-1.56) \]
\[ + 0.03 P_0 - 0.92 \]
\[ (3.22) \quad (-2.42) \]
\[ R^2 = 0.86, \quad DW = 1.79 \]

Here the demand pull term is measured in the products market directly by the use of unfilled orders. Terms for wage-price expectations as measured using a distributed lag (\( \bar{w} \)) and adjusted for constant long term productivity growth, i.e., \( (y-n) = 0.49 \), are kept separate from shorter term increases in wages and shorter term improvements in productivity. The estimates use quarterly data for the U.S. from 1960-1977. These results show that productivity growth slows price increases (at the 10% level) even over these short quarterly periods, whereas crude oil price increases (measured with a distributed lag) aggregate inflation.

L. A. Dicks-Mireaux (1961) has included the rate of change in productivity \( (y-n) \) in his price equation, and using annual U.K. data for 1946-1959 has obtained:

\[ p = 0.27 w = 0.54(y-n) + 0.21 p_{m-1/4} + 2.47 \]
\[ w = -2.78 U_{1/2} + 0.30 p_{-1} + 0.16 p_{-1} + 3.90 \]

where \( p_{m1/4} \) is annual percentage increase in import prices logged by one quarter, and other variables are as defined previously.