No. 1668

A MIXED BLESSING: NATURAL RESOURCES AND ECONOMIC GROWTH

Thorvaldur Gylfason, Tryggvi Thor Herbertsson and Gylfi Zoega

HUMAN RESOURCES

Centre for Economic Policy Research

ISSN 0265-8003

A MIXED BLESSING: NATURAL RESOURCES AND ECONOMIC GROWTH

Thorvaldur Gylfason, Tryggvi Thor Herbertsson and Gylfi Zoega

Discussion Paper No. 1668
July 1997

Centre for Economic Policy Research
25–28 Old Burlington Street
London W1X 1LB
Tel: (44 171) 878 2900
Fax: (44 171) 878 2999
Email: cepr@cepr.org

CEPR Discussion Paper No. 1668

July 1997

ABSTRACT

A Mixed Blessing: Natural Resources and Economic Growth*

This paper diagnoses the symptoms of the Dutch disease in a two-sector stochastic endogenous growth model. A productive, low skill-intensive primary sector causes the currency to appreciate in real terms, thus hampering the development of a high skill-intensive secondary sector and thereby reducing growth. Moreover, the volatility of the primary sector generates real exchange rate uncertainty, and may thus reduce investment and learning in the secondary sector and hence also growth. Cross-section and panel regressions based on data for 125 countries in the period 1960–92 confirm a statistically significant inverse relationship between the size of the primary sector and economic growth, but not between the volatility of the real exchange rate and growth.

JEL Classification: O41, Q32
Keywords: endogenous growth, natural resources, Dutch disease, learning-by-doing

Thorvaldur Gylfason
Faculty of Economics and Business Administration
University of Iceland
101 Reykjavik
ICELAND
Tel: (354) 525 4533
Fax: (354) 552 6806
Email: gylfason@rhi.hi.is

Tryggvi Thor Herbertsson
Institute of Economic Studies
University of Iceland
101 Reykjavik
ICELAND
Tel: (354) 525 4500
Fax: (354) 552 6806
Email: tthh@rhi.hi.is

Gylfi Zoega
Department of Economics
Birkbeck College
7–15 Gresse Street
LONDON
W1P 1PA
UK
Tel: (44 171) 631 6406
Fax: (44 171) 631 6416
Email: gzoega@econ.bbk.ac.uk

*This paper is produced as part of a CEPR research programme on *Product Market Integration, Labour Market Imperfections and European Competitiveness*, supported by a grant from the Commission of the European Communities under its Human Capital and Mobility Programme (no. ERBCHRXCT930235). The authors wish to thank Fridrik Mar Baldursson, J Michael Orszag and Ron Smith for useful comments and Haukur C Benediktsson for research assistance. The usual disclaimer applies.

Submitted 2 May 1997

NON-TECHNICAL SUMMARY

Economic growth is a complex phenomenon. Even so, the empirical growth literature of recent years has identified only a couple of robust determinants of the rate of growth of per capita GDP across countries: initial GDP and the ratio of investment to GDP. A few more variables have been suggested by some writers: foreign trade, school enrolment, inflation, political instability, corruption, inequality, and the preponderance of the primary sector in the economy. In this paper, we focus on the links between the primary sector and growth.

We contend that the division of GDP between primary and secondary production affects economic growth in the long run. The statistically significant negative correlation between the share of the primary sector in the labour force and the ratio of investment to GDP across countries suggests that excessive primary production may inhibit growth by reducing investment in physical capital. The main hypothesis in this paper, however, is that an abundance of natural resources and a corresponding preponderance of primary production tend to inhibit economic growth by discouraging investment in human capital.

The paper is intended to shed further light on the contribution of human capital to economic growth by pointing out the possible role of sectoral differences in human-capital creation in explaining cross-country differences in growth. In particular, we claim that the primary sector, which includes agriculture, fishing, forestry, and mining, may need – and also generate – less human capital than services and manufacturing. We suspect that, for this reason, countries with a comparative advantage in the production of primary output may consequently experience less economic growth.

Our explanation as to why countries with a stagnant primary sector sometimes do not develop a thriving secondary sector and thus sustain growth involves the Dutch disease: the dominant primary sector causes the currency to appreciate in real terms, thereby reducing the profitability of other exports. We extend this argument by describing how a floating exchange rate regime can provide (social) insurance for the dominating primary export industry at the cost of increased exchange rate uncertainty for all other industries. These problems magnify the 'distortions' in the intersectoral allocation of resources, so that economic growth is further reduced.

To tackle these issues, we lay out a simple stochastic endogenous growth model with a tradable and a non-tradable sector, where the former has access to two different kinds of production technology, which we refer to as the primary sector and the secondary sector. We assume that learning-by-doing and knowledge spillovers only occur in the secondary sector. We describe the conditions necessary for the emergence of a secondary sector, which escapes diminishing returns and generates growth, in the presence of a dominant primary sector. These conditions involve a 'growth threshold', in the following sense: the real exchange rate must be low enough for investment (in human capital) to take place in the secondary sector and thus for the economy to grow. When, on the other hand, the real exchange rate appreciates beyond a certain level, there is no such investment and no growth.

Because of the human capital generation and knowledge spillovers in the secondary sector – externalities – it would be socially optimal for investment in the secondary sector to start before the growth threshold is reached. Further, an increase in primary sector productivity causes the currency to appreciate in real terms, thereby moving the real exchange rate away from the growth threshold. This is the Dutch disease.

The model implies that the rate of growth of output varies inversely with productivity in the primary sector, because a larger primary sector causes a real appreciation of the currency and thus reduces the profitability of investment in the secondary sector. Similarly, growth is directly related to foreign indebtedness in the model, because the increase in the non-interest external surplus required to service increased foreign debt depreciates the currency in real terms and stimulates growth.

These and other related hypotheses are tested using cross-section and panel data constructed from the Penn World Tables and the World Data Bank. The data span the years 1960–92. We start with the standard Barrovian cross-section regression model, using the following variables as regressors: initial GDP (1960), the investment/GDP ratio, the initial share of primary production in the labour-force (1965), the initial share of primary exports in total exports (1970), the ratio of external debt to GDP, real exchange rate volatility, initial primary and secondary school enrolment rates (1965), and a dummy for Africa. The two measures of the size of the primary sector differ in that the primary export share includes extraction industries (such as mining, oil, etc.), whereas the primary labour share does not. Two sets of estimates are presented: (1) cross-section estimates, where each country in the sample is represented by a single observation; and (2) panel estimates, where the dynamic properties of the data are taken into consideration by representing each country by several observations, each corresponding to a five-year interval.

Our main findings are the following: (1) the per capita incomes of poor countries converge to those of rich countries at a slow pace – about 0.8% to 1.6% per year; (2) an increase in the investment rate from 20% to 30% of GDP from one country or period to another increases the rate of growth per capita by 1.1% to 1.5% per year, other things being equal; (3) an increase in either the share of the primary sector in the labour force or in the share of primary exports in total exports from 5% to 30% from one country or period to another reduces per capita growth by about 0.5% per year, other things being equal; (4) increased foreign indebtedness is inversely related to growth, contrary to the prediction of the model, but we point out that outside long-run equilibrium, where overvalued currencies are typically accompanied by continuous foreign debt accumulation, the model would predict slower growth in keeping with our empirical findings; (5) exchange rate volatility has no significant effect on growth, indicating that the Dutch disease may manifest itself through the level of the real exchange rate rather than through its variability; and (6) the inclusion of the primary sector in the regressions undermines the Africa dummy in most cases, which suggests that the dummy for Africa may have served as a proxy for the primary sector and related variables in earlier work.

Our main conclusion is that the statistically significant inverse relationship between the size of the primary sector and the average rate of growth of output across countries appears to dominate the positive relationship between education (i.e. school enrolment) variables and growth; the effects of schooling generally drop in size and significance when primary employment or primary exports are added to the regressions. This leads to our conjecture that the size of the primary sector may give a better picture of the level and changes in human capital across countries than school enrolment rates, which measure output by input.

1 Introduction

Since the second world war it has become quite clear that rapid economic growth is available to those countries *with adequate natural resources* (italics added) which make the effort to achieve it.

W. Arthur Lewis (1968, p. ix)

Economic growth is a complex phenomenon. Nevertheless, the empirical growth literature of recent years has identified only a couple of robust determinants of the rate of growth of per capita GDP across countries: initial GDP and the ratio of investment to GDP.[1] A few more variables have been suggested by some writers: foreign trade, school enrolment, inflation, political instability, corruption, inequality, and the preponderance of the primary sector in the economy.[2] In this paper, we focus on the links between primary production and growth.

We contend that the division of GDP between primary and secondary production affects economic growth in the long run. A casual look at the evidence seems to support this view. There is, for example, a statistically significant negative correlation between the initial share of the primary sector in the labor force and the average ratio of investment to GDP (Figure 1). This suggests that excessive primary production may inhibit growth by reducing investment in physical capital. If this is the sole channel through which primary production affects growth, however, then the inclusion of investment in a cross-country growth regression should render the effect of primary production on growth statistically insignificant.

<Insert Figure 1 about here>

Our main hypothesis in this paper is that an abundance of natural resources and a corresponding preponderance of primary production tend to inhibit economic growth by reducing investment in *human* capital.

[1] See, e.g., Levine and Renelt (1992) and Barro and Sala-i-Martin (1995).

[2] On trade, see Edwards (1992, 1993). Schooling is covered in Barro (1991) and Mankiw, Romer, and Weil (1992) and inflation in Fischer (1991, 1993), Bruno and Easterly (1995), and Gylfason and Herbertsson (1996). On political instability, see Barro, and Sala-i-Martin (1995). Corruption is taken up in Mauro (1995) and inequality, in Persson and Tabellini (1994). Finally, on primary production, see Sachs and Warner (1995).

The role of human capital in empirical models of economic growth has been emphasized lately by Barro (1991), Mankiw, Romer, and Weil (1992), and Barro and Sala-i-Martin (1995). The idea goes back, at least, to Lewis (1955) and Nelson and Phelps (1968), who claim that educated workers are faster learners, as education teaches people to learn;[3] see also Romer (1986, 1990) and Lucas (1988). In the context of endogenous growth models, a faster rate of learning and knowledge spillovers free the economy from diminishing returns and thus facilitate sustained growth.

This paper is intended to shed further light on the role of human capital in models of economic growth by pointing out the possible role of sectorial differences in education in explaining cross-country differences in growth. In particular, we claim that the primary sector, which includes agriculture, fishing, and forestry, may need–and also generate–less human capital than services and manufacturing.[4] We suspect that, for this reason, countries with a comparative advantage in the production of primary output may consequently experience less economic growth.[5] This may help explain the significance of measures of human capital in cross-country growth regressions reported in Barro (1991), Mankiw, Romer, and Weil (1992), and Barro and Lee (1993).

Why do not countries, which specialize in a stagnant primary sector, develop a thriving secondary sector and thus sustain growth? A plausible answer to this question involves the *Dutch disease*:[6] the dominant primary industry causes the currency to appreciate in real terms, hence reducing

[3]Empirical support for this idea is provided by Mincer and Higuchi (1988), who find a positive relationship between the rate of return to education and the rate of technological progress across industries, using U.S. and Japanese data.

[4]British and German data indicate that the proportion of workers with little or no education is higher in agriculture, fisheries, and forestry than in most other sectors. The proportion of primary-sector workers with no vocational degrees is 76 per cent in Britain and 52 per cent in West Germany (Prais, 1995). In Germany, this is by far the highest proportion of less advantaged workers. A distant second is hotels and catering, with a proportion of 42 per cent. In Britain, a few sectors match our primary sector: distributive trades (78 per cent), hotels and catering (77 per cent), insurance, banking, and finance (76 per cent), the manufacturing industries of food, drink, and tobacco (74 per cent), and textiles, leather, and footwear (81 per cent).

[5]Earlier explanations have focused on rent-seeking behavior in resource-rich countries (Lane and Tornell, 1995), the limited importance of forward and backward linkages from primary exports (Hirschman, 1958), and the expected future fall in the relative demand for primary goods.

[6]See Bruno and Sachs (1982) and Buiter and Purvis (1982).

the profitability of other exports.[7,8] We extend this argument by describing how a floating exchange rate regime can provide (social) insurance for the dominating primary export industry at the cost of increased exchange rate uncertainty for all other industries.[9] A similar argument would apply to other systems of insurance, such as agricultural price support schemes.[10] These problems magnify the 'distortions' in the intersectoral allocation of the factors of production, so that economic growth is further reduced.

The following section lays out a simple stochastic endogenous growth model with a tradable and a nontradable sector, where the former has access to two different kinds of production technology. We refer to one of these as a *primary* sector, and the other as the *secondary sector*, and assume that learning-by-doing and knowledge spillovers only occur in the secondary sector. We describe the conditions necessary for the emergence of a secondary sector, which escapes diminishing returns and generates growth, in the presence of a dominant primary sector. Section 3 tests the implications of the model based on both a cross section and a panel of countries. Section 4 concludes.

2 Endogenous Growth with a Smothering Primary Sector

2.1 Primary Production and the Real Exchange Rate

The economy initially produces tradable goods, y_1^T, in a primary sector, where output depends on the relative price of tradable goods in terms of nontradables, $\lambda = p^T/p^N$, i.e., the real exchange rate:

$$y_1^T = B_1 + \beta\lambda, \quad \beta > 0 \tag{1}$$

[7]The appreciation of the British Pound following the Britain's offshore oil discoveries in the late 1970s is one example of this effect. Norway is another case in point: the country's oil exports have crowded out other exports virtually one for one relative to GDP since the oil discoveries in the early 1970s.

[8]Sachs and Warner (1995) report that countries with a high ratio of natural resource exports to GDP at the beginning of the 1970s generally had a low average growth rate during the 1970s and the 1980s.

[9]This effect would only be reinforced if monetary policy was aimed at helping the export industry in times of trouble.

[10]See Newbery and Stiglitz (1983).

B_1 represents productivity in the primary sector, which is subject to productivity shocks that follow a geometric Wiener process, $dB_1 = \sigma B_1 dW$, without drift. The domestic demand for the tradable primary good is also described by a simple linear function of the real exchange rate:

$$c^T = A - \alpha\lambda, \quad \alpha > 0 \tag{2}$$

where A represents autonomous demand. The real exchange rate is determined by the intertemporal budget constraint. This requires the economy to export (import) enough tradable goods to pay (consume) interest on foreign debt (assets). In the absence of trend productivity growth, this translates into equation (3), where D denotes the noninterest external surplus–measured in units of tradable goods–needed to meet interest payments on foreign debt in order to keep its stock constant. A constant level of foreign debt is assumed throughout the paper.

$$D = y_1^T - c^T = B_1 - A + (\alpha + \beta)\lambda \tag{3}$$

Equations (1)-(3) give the real exchange rate, λ, as a function of B_1, D, A, and the effects of the real exchange rate on primary sector output supply and demand, β and α. For a given value of the noninterest surplus, taking the total differential of (3) and using Ito's Lemma gives

$$d\lambda = -\left(\frac{1}{\alpha + \beta}\right)\sigma B_1 dW \tag{4}$$

Changes in the real exchange rate are thus a function of the stochastic process followed by B_1. This is the same process as the one followed by productivity except for the first term on the right-hand side, which is negative. Thus a productivity improvement in the primary sector leads to a real appreciation of the currency: λ falls. The relationship between the real exchange rate and B_1 is commonly referred to as the Dutch disease: a productive primary sector causes the currency to appreciate in real terms (i.e., λ to fall), hence making it difficult for other potential export industries to establish themselves or for existing ones to thrive. The magnitude of the effect on the real exchange rate depends on supply and demand elasticities of primary output of tradables, hence β and α. If these two parameters are small, the effect on the real exchange rate is large. Thus we expect the symptoms of the Dutch disease to be particularly serious in countries with low elasticities. Moreover, real exchange rates will be more volatile in such countries: the variance term in equation (4) will be larger. We discuss the consequences of this below.

2.2 When Can a Secondary Sector Emerge?

Now imagine that tradable output could also be produced by using an alternative technology in the secondary sector. Moreover, assume that its share of employment is initially small: $l_2 = \epsilon$. Thus we imagine that there is one type of (tradable) output and two types of production technology, primary and secondary. Both have diminishing private returns to labor. However, they differ in two ways as follows:

ASSUMPTION 1: *No training of labor is required in the primary sector, while in the secondary sector, hiring involves training, i.e., investment in human capital.*

We make this assumption only to simplify the model; its relaxation would not affect any of our results.

ASSUMPTION 2: *There is learning-by-training in the secondary sector, involving instantaneous knowledge spillovers.*

This implies constant returns to scale at the social level in the secondary sector. This follows from our presumption–supported by the studies mentioned above–that workers in the secondary sector are more skilled on average and, for that reason, more open to new production processes while in training.[11]

The production technology in the secondary, tradable sector can now be described as follows for the representative firm:

$$y_2^T = B_2 l_2^\alpha L_2^{1-\alpha} \tag{5}$$

where y_2^T is output, B_2 is an exogenous measure of technology in the secondary sector, l_2 is labor in the secondary sector, and L_2 is the aggregate labor force used there. The number of firms is $n = L_2/l_2$. The inclusion of L_2 in the production function reflects the effect of learning by doing (training):

[11] Alternatively, we could argue that labor in the two sectors is equally skilled and able to learn but that the primary sector ultimately cannot escape diminishing returns at the social level because of the constraints imposed by nature. See Herbertsson and Sörensen (1996) for a two-sector CGE model where growth is constrained by a renewable natural resource stock.

a new worker trained in the secondary sector increases aggregate knowledge about production in the sector through instantaneous knowledge spillovers. We assume that B_2 is deterministic and fixed.

The exchange rate regime and the (initially) dominant share of primary output in exports reduce the risk of production in the primary sector. Real exchange rate movements reduce uncertainty in the primary sector, while they increase it in the (hypothetical) secondary sector: starting secondary production is risky, because the real exchange rate and B_2 are not correlated.

B_1 and B_2 have no trend, so the only potential source of technological progress is learning-by-doing in the secondary sector. Accordingly, until a secondary sector emerges, there is no growth in this economy. This means that the higher the value of B_1, the higher will be the real exchange rate (i.e., λ will be lower), and hence the more difficult it will be for a secondary sector to take off, i.e., for growth to take place. We will return to this theme shortly.

Because of the training costs in the secondary sector, we treat labor in that sector as a quasi-fixed asset. The decision to hire workers in that sector is inherently an intertemporal (investment) decision. We will use the methods described by Dixit and Pindyck (1994) to solve the optimization problem faced by the representative firm in this sector. We denote the cost of hiring by T per worker.[12] Workers in the secondary sector quit with probability q. This is due to random preferences, which cause workers to switch between firms for non-wage reasons with a fixed probability per unit of time.[13] Since firms, when hiring new workers, know only the average quit rate, but not an individual's exposure to personal factors, it is this average quit rate that they take into account when making their hiring decisions.

We take L_2 to be indepentent of the quit rate. Thus we assume that quitting does not reduce aggregate knowledge in the industry because either the workers quit to start their own firms within the industry or they pass on their know-how to remaining workers before leaving for other industries.

Using Ito's Lemma, we get the following Bellman equation, which describes the value of the stock of trained, secondary-sector workers l_2–i.e., the

[12] One can imagine this cost to consist of lost output due to the need to train newcomers.

[13] This follows Calvo (1979), where the quit rate is endogenized by making it a function of wages.

value of the firm, V–when the value of future hires in the sector is ignored:

$$rV(l_2, \lambda) = \lambda B_2 l_2^\alpha L_2^{1-\alpha} - wl_2 - ql_2 V_{l_2} + \frac{1}{2}\left(\frac{1}{\alpha+\beta}\right)^2 \sigma^2 B_1^2 V_{\lambda\lambda} \qquad (6)$$

and r is the real rate of interest and w is the real wage measured in nontraded goods. Each firm is small enough to take the total number of workers in the industry, L_2, as given. Equation (6) is essentially an asset equation. The left-hand side variable shows the required return. The right-hand side is the sum of a dividend and an expected capital gain. The first term on the right-hand side is current output in the secondary sector. The second term shows the wage bill. The third term is the expected loss due to quits of previously trained workers. The last term is the expected change in the value of the firm in response to future changes in the real exchange rate.

The solution to differential equation (6) contains the following particular integral, V^P:

$$V^P(l_2, \lambda) = E\int_0^\infty \left[\lambda B_2 (l_2 e^{-qt})^\alpha L_2^{1-\alpha} - w(l_2 e^{-qt})\right] e^{-rt} dt \qquad (7)$$

This is the expected, present discounted value of future profits from the l_2 workers employed at time zero, measured by the difference between future output and wage payments taking into account the constant quit rate, q. The equation can be rewritten as follows:

$$V^P(l_2, \lambda) = \frac{\lambda B_2 l_2^\alpha L_2^{1-\alpha}}{r+\alpha q} - \frac{wl_2}{r+q} \qquad (8)$$

In order to find the value of the marginal secondary-sector worker, we take the derivative of (8) with respect to l_2:

$$v^P(l_2, \lambda) \equiv V_{l_2}^P(l_2, \lambda) = \frac{\alpha \lambda B_2 l_2^{\alpha-1} L_2^{1-\alpha}}{r+\alpha q} - \frac{w}{r+q} \qquad (9)$$

We also need to calculate the value of the option to hire a worker in the secondary sector, i.e., the complementary function. Now, define v^G as the value of the option to hire the marginal worker, where G denotes general:

$$v^G(l_2, \lambda) \equiv V_{l_2}(l_2, \lambda) \qquad (10)$$

and differentiate the homogenous part of equation (6) with respect to l_2. This gives

$$(r+q)\,v = \left[-ql_2 v_{l_2} + \frac{1}{2}\left(\frac{B_1}{\alpha+\beta}\right)^2 \sigma^2 v_{\lambda\lambda}\right] \tag{11}$$

The general solution is:

$$v^G(l_2,\lambda) = C_1\Lambda^{\gamma_1} + C_2\Lambda^{\gamma_2} \tag{12}$$

where $\Lambda = \alpha\lambda B_2 l_2^{\alpha-1} L_2^{1-\alpha}$, γ_1 and γ_2 are the roots of the characteristic equation[14] and $\gamma_1 > 1$ and $\gamma_2 < 0$. The negative root is eliminated, because we want the value of the option to go to zero as the real exchange rate approaches zero. This simplifies the general solution to:

$$v^G(l_2,\lambda) = C_1\Lambda^{\gamma_1} \tag{13}$$

The value of the marginal employed worker in the secondary sector is then equal to v^P and the option value of hiring him is equal to v^G. The latter is part of the cost of hiring the worker. When a new worker is hired and the direct training costs, T, incurred, the option of hiring him in the future is sacrificed. The marginal cost of hiring a new worker is, therefore, equal to the sum of T and v^G. The threshold value of the real exchange rate at which the representative firm starts hiring new workers, λ_H, is defined by the following two conditions:

Value-matching condition

$$\frac{\alpha\lambda_H B_2 l_2^{\alpha-1} L_2^{1-\alpha}}{r+\alpha q} - \frac{w}{r+q} = T + C_1\Lambda_H^{\gamma_1}, \quad \Lambda_H \equiv \alpha\lambda_H B_2 l_2^{\alpha-1} L_2^{1-\alpha} \tag{14}$$

The left-hand side of this equation is the marginal benefit from hiring a new worker. The right-hand side is the marginal cost, which is equal to the sum of the direct training cost and the indirect cost because of the sacrificed option of hiring him later.

Smooth-pasting condition

$$\frac{\alpha B_2 l_2^{\alpha-1} L_2^{1-\alpha}}{r+\alpha q} = C_1\gamma_1\Lambda_H^{\gamma_1-1}\alpha B_2 l_2^{\alpha-1} L_2^{1-\alpha} \tag{15}$$

[14]The characteristic equation is: $\frac{1}{2}\left(\frac{B_1}{\alpha+\beta}\right)^2\sigma^2\gamma(\gamma-1) - q(\alpha-1)\gamma - (r+q) = 0$.

This condition requires the derivative of the marginal benefit and the marginal cost with respect to the real exchange rate to be equal at the hiring threshold.

Solving equation (15) for C_1 and substituting into (14) gives

$$\lambda_H = \left(\frac{\gamma_1}{\gamma_1 - 1}\right)\left(\frac{(r+\alpha q)\,(w/(r+q)+T)}{\alpha B_2 l_2^{\alpha-1} L_2^{1-\alpha}}\right) \tag{16}$$

Combining equations (16), (1), (2), and (3) gives

$$\lambda(D,\alpha,\beta,B_1,A) \gtreqless \left(\frac{\gamma_1}{\gamma_1 - 1}\right)\left(\frac{(r+\alpha q)\,(w/(r+q)+T)}{\alpha B_2 l_2^{\alpha-1} L_2^{1-\alpha}}\right) \tag{17}$$

The implications of the model are summarized by this equation. It defines a threshold value of the real exchange rate–a *growth threshold*–such that if the exchange rate is higher, no investment takes place in the secondary sector, while if it is lower, there is investment in the sector. Thus, below the threshold, there is no economic growth, while above it, the economy grows continuously in the absence of further changes in the real exchange rate.

The first term on the right-hand side is positive and greater than one. It makes the firm wait beyond the point at which the present discounted value of future profits is equal to the cost of training the worker. The firm waits longer, because it seeks more information about future values of the real exchange rate: time is of value.

We can summarize the key implications as follows:

- *Knowledge externalities and overvaluation.* The knowledge externalities in the secondary sector raise the growth threshold. The private marginal product of labor is lower than the average product of labor, which is the social marginal product.[15] The average product of labor in our representative firm is:

$$\frac{y_2^T}{l_2} = B_2\left(\frac{L_2}{l_2}\right)^{1-\alpha} = B_2 n^{1-\alpha} \equiv f(n) \tag{18}$$

  where n is the number of firms in the secondary sector as before. The marginal product is:

$$\partial y_2^T/\partial l_2 = f(n) - nf'(n) = B_2 n^{1-\alpha} - (1-\alpha)B_2 n^{1-\alpha} \tag{19}$$

[15] This follows from the central planner's problem.

which is thus lower than the average product. Therefore, it would be optimal for investment in the secondary sector to start before the threshold of equation (17) is reached.

- *The real exchange rate and external debt.* The actual value of the real exchange rate is a function of the noninterest external surplus required to keep the stock of foreign debt, D, constant; the effect of the real exchange rate on the supply and domestic demand for primary output, β and α; productivity in the primary sector, B_1; and autonomous demand for primary output, A:

$$\lambda_D > 0, \quad \lambda_\beta < 0, \quad \lambda_\alpha < 0, \quad \lambda_{B_1} < 0, \quad \lambda_A > 0 \tag{20}$$

A more productive primary sector causes the currency to appreciate in real terms, hence moving λ further below its growth threshold. This is the Dutch disease: growth is reduced even further. A rise in foreign indebtedness, which makes a higher noninterest external surplus necessary, causes a real depreciation of the currency, and we move up towards the threshold. Thus increased external debt can spur economic growth by making investment in the secondary (tradable) goods sector profitable. Finally, a given positive level of D requires a higher value of λ, the more so the lower the sensitivity of tradable goods output and consumption to changes in the real exchange rate.[16]

- *Exchange rate volatility.* The value of the growth threshold depends on the degree of exchange rate uncertainty,

$$\left(\frac{B_1}{\alpha+\beta}\right)\sigma$$

through γ_1, where σ is a measure of uncertainty about future primary sector productivity and B_1 is the current level of productivity in that sector. Increased uncertainty reduces γ_1 and thus increases the first term on the right-hand side of (17): the threshold rises. Thus, the greater the size of productivity shocks in the primary sector, the higher is the growth threshold. Intuitively, firms wait longer before entering the secondary sector, because the future is less certain: they wait longer for information about future real exchange rates. Since this

[16]This implication is reversed if D is negative, i.e., if there are foreign assets.

is due entirely to the exchange rate regime, we conclude that a flexible exchange rate exacerbates the market failure described above: the growth threshold rises further away from its social optimum. This is a different, although less noticed, form of the Dutch disease. By how much the threshold is raised, depends on the elasticity of supply and demand of tradable output. Low elasticities require greater changes in the real exchange rate.

The threshold also depends on real wages, w; training costs in the secondary sector, T; the real rate of interest, r; the average quit rate in the secondary sector, q;[17,18] and the level of the exogenously given productivity in the sector, B_2. High wages make it less profitable to train new workers in the secondary sector and, obviously, so do also high training costs. Similarly, both high interest rates and high quit rates make investment in the secondary sector less profitable and hence require a higher real exchange rate for investment to occur.[19] Moreover, the more productive the secondary sector, the lower the growth threshold. Finally, the more firms there are in the secondary sector, n, the higher is its marginal product and the lower is the threshold.

The question arises whether growth can continue indefinitely once the currency has depreciated enough, so that λ has reached the growth threshold. As there are constant returns to labor at the industry level, this appears to be the case. But equation (3) tells us that the higher is productivity in the primary sector, B_1, the higher is the real exchange rate (i.e., λ is lower), given a fixed level of external indebtedness. Thus the currency would appreciate in real terms as the secondary sector starts training more workers and hence raising its productivity, $B_2 L_2^{1-\alpha}$. As the currency appreciates, growth in the

[17] Quit rates are not insignificant. According to Freeman (1980), quit rates in the union sector in the United States are between 1 per cent and 6 per cent of private sector salaried workers, while for the nonunion sector they are between 7 per cent and 9 per cent.

[18] Another market failure arises here if part of the training could be transferred between firms in the secondary sector. This would make the private discount rates higher than the social ones, because a worker who leaves one firm for another deprives the former of all of his human capital, while only part of it is lost from the perspective of a social planner. We have not considered this possibility here, but it is discussed extensively in Booth and Zoega (1994).

[19] The real rate of interest and the quit rate also affect the threshold indirectly through γ_1. This effect goes in the opposite direction: firms invest sooner at higher interest and quit rates, because they discount possible future losses at a higher rate, i.e., they are more willing to take risk.

secondary sector peters out. There comes a time, other things being equal, when the currency has appreciated enough in real terms to make investment in the secondary sector stop, thus stifling economic growth.

2.3 Closing the Model

Consumers live infinitely long and maximize discounted future utility, which gives the standard Ramsey rule for the consumption profile:

$$\frac{\dot{c}}{c} = \mu(r(\lambda) - \rho), \quad r'(\lambda) > 0 \tag{21}$$

where ρ is the pure rate of time preference and μ is the elasticity of intertemporal substitution. Before any investment in the secondary sector takes place, the real rate of interest is equal to the exogenous world interest rate, r^*, as domestic consumers can invest their savings abroad. Moreover, we assume that the world real rate of interest is equal to the pure rate of time preference: $r^* = \rho$. For this reason, there is initially no saving in the economy, consumption is flat, and the stock of foreign debt (assets) is fixed.

When the real exchange rate crosses the growth threshold defined by equation (17), the net supply of domestic output falls as firms in the secondary sector start using workers to train newcomers: there is domestic investment for the first time. As this is investment in human capital, we assume that foreigners do not lend capital to finance it. Consequently, this increases investment, stimulates output demand, and drives the domestic real rate of interest above the world rate. Therefore, consumption drops initially and then grows in the new steady state along with output in the secondary sector, at a higher rate than before.

3 Empirical Evidence

The empirical implications of the model of Section 2 can now be summarized as follows, where g denotes the rate of economic growth:

$$g = f(\overset{-}{B_1}, \overset{+}{D}, \overset{-}{\sigma}, \overset{-}{T}, \overset{-}{q}, \overset{+}{n}, \overset{-}{\rho}) \tag{22}$$

The rate of growth of output is a declining function of the level of productivity in the primary sector, B_1, because a larger primary sector causes a real appreciation of the currency and thus reduces the profitability of investment in the secondary sector. Similarly, a rise in the required noninterest external surplus, D, reduces the real exchange rate and stimulates growth. Increased uncertainty about future primary sector productivity, σ, raises the threshold and reduces growth, and so do also (a) an increase in the cost of training workers in the secondary sector, T; (b) an increase in the quit rate, q; and (c) a fall in the number of firms in the secondary sector, n, *ceteris paribus*. The last effect is a scale effect: there is more knowledge in a larger economy. Finally, a rise in the pure rate of time preference, ρ, reduces saving and hence also the rate of growth.

We will focus on the first three variables in equation (22) by testing the relationship between economic growth and the size and volatility of the primary sector, the latter through the volatility of the real exchange rate, and also the level of foreign debt. The key implication of the model is that an expansion of the primary sector, as, for example, brought about by an improvement in primary production technology, will reduce the rate of growth by reducing learning in the secondary sector, and hence also human capital accumulation. This effect may explain, at least in part, the apparent statistical significance of human capital variables such as school enrolment rates in the growth studies mentioned above. Thus economies where human capital is created through secondary sector training, may choose to devote resources to provide formal education. This might be justified in terms of lower training costs.[20] Alternatively, a good education system may be conducive to the creation of a (human-capital generating) secondary sector. Figures 2 to 4 support our claim by displaying a strong and statistically significant inverse correlation between the initial share of the primary sector in the labor force and the initial enrolment rate in primary schools (Figure 2), secondary schools (Figure 3), and tertiary schools (Figure 4).

<Insert Figures 2, 3, and 4 about here>

Of course, some alternative explanation for this relationship may exist. In such case, we claim, the relationship between growth and school enrolment rates may be spurious, simply reflecting the effect of an omitted variable: the size of the primary sector. These correlations suggest that primary production may be a useful proxy for human capital in cross-country growth regressions. To find out, we include school enrolment rates and measures of

[20] See Arulampalam and Booth (1996) on the effect of general education on training costs.

primary production, measured both by the share of primary production in the labor force and the share of primary exports in total exports, side by side among other explanatory variables in a Barrovian growth regression to see which contributes the most to the explanation of differences in growth rates across countries.

3.1 The Data

We use unbalanced cross-section data constructed from the Penn World Tables and the World Data Bank. The data cover the period 1960-1992. In the first regression (see Table 1), which corresponds to a $\beta-$convergence regression, we use data for 125 countries. As we move towards a more general model specification, the number of countries decreases until, in the fifth regression, we are left with 65 countries. This method enables us to use as much as possible of the information available for each model, but it leaves us with parameters that are not directly comparable across models. For a detailed description of the data, see Appendix A.

3.2 Cross-Section Estimation

We start with the standard Barrovian cross-section regression model. The regressors are: initial GDP (1960), the investment/GDP ratio, the initial share of primary production in the labor force (1970), external debt in proportion to GDP, real exchange rate volatility, initial primary and secondary school enrolment rates (1965), and a dummy for Africa.

The first regression is the standard convergence regression. In regression (2) we add the two standard proxies for human capital, the initial primary and secondary school enrolment rates, and in regressions (3a)-(5a) we add, one at a time, the variables implied by our model, i.e., the initial share of the primary sector in the labor force, the ratio of external debt to GDP, and an index of real exchange rate volatility. In regressions (3b)-(5b) we use the ratio of primary exports to total exports of goods and services instead of the share of the primary sector in the labor force. In regressions (6a)-(8a) we add the same three variables, now excluding the schooling variables from the regressions. And finally, in regressions (6b)-(8b) we include the ratio of primary exports to total exports, now excluding the school enrolment variables. In Table 1 we report our findings on the relationship between growth and the explanatory variables, the standard errors of estimation (SE), the adjusted coefficient of determination ($\bar{R}^2$), and the degrees of freedom (DF).

<Table 1 about here>

To test for the robustness of our results we also tried the Huber (1973) robust estimator, and thus in effect imposed a normal distribution on the residuals. The results (not reported here) remained virtually the same as in Table 1. Therefore, by virtue of the central limit theorem, we are not concerned with the sensitivity of our results to outliers.[21]

Table 2 shows the correlations between the orthogonal components of the regressors and the per capita growth rate with and without the school enrolment variables.[22]

<Table 2 about here>

The partial correlation between per capita growth and investment and external indebtedness is significant at the 1 per cent level in both equations. The hypothesis of zero correlation cannot be rejected for primary and secondary education and the exchange rate volatility index at reasonable levels. The same hypothesis is marginally rejected for primary labor at the 5 per cent level in the first equation, but cannot be rejected in the second. A similar pattern is observed when the share of the primary sector in the labor force excluding extraction industries is replaced by the share of primary exports in total exports, and the estimates become more precise. The gain of precision is understandable in view of the fact that the correlation between the share of primary exports in total exports and primary and secondary school enrolment rates are smaller (-0.23 and -0.52, respectively) than the correlations between the share of the primary sector in the labor force and primary

[21] We also ran the regressions using a consistent covariance matrix allowing for heteroscedasticity. The standard errors thus obtained did not deviate substantially from the ones reported, from which we infer the absence of heteroscedasticity.

[22] Partial correlations provide a direct measure of the strength of the relationship between the dependent and independent variables. The partial correlation coefficents are estimated from the sample data as follows: a) fit an OLS regression with growth as dependent variable and independent variables $X_2, X_3, ..., X_K$; b) fit an OLS regression with X_1 as dependent variable and independent variables $X_2, X_3, ..., X_K$; c) compute the sample correlation between the residuals from the regressions in steps a) and b). The purpose of steps a) and b) is to remove the effects of $X_2, X_3, ..., X_K$ on growth and on X_1 before computing the sample correlation.

and secondary school enrolment (−0.41 and −0.74, respectively). These correlations may in turn be viewed as an indication that extraction industries (mining, etc.) generally use somewhat better educated labor on average than agriculture and fisheries. The remainder of this section describes the results obtained in further detail.

Initial GDP: The coefficients on this variable represent $\beta-$convergence rates. The parameter reflects the speed at which poor countries converge to rich ones in terms of GDP. The coefficient is significantly different from zero in all the regressions, but small, implying a convergence speed of 0.8 per cent to 1.6 per cent per year. This result is, however, in line with the findings of Nerlove (1996) and Gylfason and Herbertsson (1996) for large panels of countries.

Investment: This variable measures investment as a proportion of GDP. The parameter is significant at the 1 per cent level in all the regressions. An increase in investment/GDP from 20 per cent to 30 per cent from one country to another would, according to regressions (1) to (8b), increase the growth rate per head by 1.1 per cent to 1.5 per cent a year, *ceteris paribus*. These findings rhyme well with those of Levine and Renelt (1992) and Sachs and Warner (1995).

Initial school enrolment: The primary enrolment rate is significant at the 1 per cent level in regression (2), and is marginally significant at the same level, when the labor share in primary production is added to the regression; see regression (3a). The parameter becomes insignificant, however, when foreign debt and exchange rate volatility are added to the regression. This seems to support our hypothesis, at least in part, that the orthogonal component of the primary labor share and education crowds out the effects of school enrolment on growth. The secondary enrolment rate is insignificantly different from zero in all the regressions, a result which confirms the findings of Wolff (1994) when controlling for catchup effects (convergence).

Labor in primary sector: This variable appears with the right sign everywhere. The hypothesis of zero coefficients is rejected at the 5 per cent level in all the regressions except (4a) and (5a). According to Table 2, a partial correlation between the share of labor in primary production and economic growth is marginally rejected when the effect of school enrolment is included. This relationship is not rejected, however, when schooling is left out of the regressions. This gives us a reason to believe that these two effects should not be included in a regression model simultaneously. Further, in view of the strong correlation between schooling and primary labor shown in Figures 2 to 4, multicollinearity is very likely a problem.

The effect of the primary sector on growth is quite strong. If the share of the primary sector in the labor force increases from 5 per cent to 30 per cent from one country to another, per capita output growth drops by about 0.5 per cent per annum, *ceteris paribus*. Sachs and Warner (1995) report a sizable effect of an increase in the share of primary exports in GDP on growth in a sample of 98 countries. Gylfason and Herbertsson (1996) and Gylfason (1997) also report similar results, based on different data sets: an increase in the share of primary exports to GDP from 5 per cent to 30 per cent reduces per capita growth by 0.5 per cent to 1 per cent or more.

Export of primary products: The primary sector labor share does not include labor in extraction industries, because the requisite data are not available. However, we also ran the regressions using the share of primary exports in total exports instead of the primary sector labor share. Regressions (3b)-(5b), now including extraction industries, show that the parameters on this variable are significant and stable. When the school enrolment variables are excluded from the regressions (regressions (6b)-(8b)), the parameters remain statistically significant.

External debt: The parameter on this variable is significantly negative throughout. The partial correlation between economic growth and foreign debt is correspondingly significant and large, see Table 2. Our model in Section 2 predicts a positive effect of external steady-state debt on growth, because more debt entails a lower real exchange rate. However, our model does not explicitly include a phenomenon that is undoubtedly important in practice: the economies most burdened with debt may not be in long-run equilibrium. They typically have overvalued currencies accompanied by continuous debt accumulation. In this case, our model would predict slower growth. This possibility seems to warrant further scrutiny in future work.

Exchange rate volatility: This variable is statistically insignificant everywhere. We also ran regressions (not reported) using both the variance of the labor share in primary production and of GDP. Both variables entered the regressions with the wrong sign, but were not statistically different from zero. This suggests that the Dutch disease may manifest itself through the level of the real exchange rate, rather than through its variability.

Africa: The Africa dummy is significant in regressions (1)-(2) where the labor share is not included. In eight of the remaining twelve regressions, the primary labor share undermines the African connection. We also ran the regressions without the Africa dummy, but the results obtained in regressions

(3a) to (8b) remained virtually unchanged.

3.3 Panel Estimation

To investigate the dynamic properties of the data we employ the random effects panel model. The data span the same period (1960-1992) as before and comprise a maximum of seven five-year averages and a minimum of one for each variable; therefore, the panel data are said to be unbalanced. Because the subperiods are only five years, we do not test for the effects of exchange rate volatility, as the estimated variance of that variable can hardly be expected to be consistent with only five observations.

In Table 3 we report our findings on the relationship between per capita growth and its determinants using the random effects panel model.

<Table 3 about here>

As in the cross-section regressions, we also ran the regressions using a robust estimator. The results reported remained virtually unchanged, so that we need not be concerned with potential nonnormality due to outliers. We also ran some of the regressions using the fixed effects panel model, and all the parameters remained virtually unchanged except the convergence parameter, which increased substantially.

Regressions (1)-(3a) yield similar coefficients on initial GDP as the cross-section regressions. When external debt is added (regressions (4a) and (6a)), the magnitude of the convergence parameter increases substantially, from approximately 1 per cent to almost 6 per cent in regression (4a) and to almost 4 per cent in regression (6a). The parameters on the export share are less significant than before. Because the share of primary exports in total exports is less closely correlated with education than is the labor share of the primary sector excluding extraction industries, it is natural that the primary export share makes a smaller contribution than the primary sector labor share to the growth equations. However, regressions (4a) and (6a) should be taken with a grain of salt, because the number of observations is small compared with the other regressions.

The parameters on investment are approximately the same in the cross-section and panel regressions.

The parameters on primary education seem more robust in the panel in the sense that the primary education variable survives the introduction of primary labor into the panel regression. Secondary education shows up with the wrong sign everywhere. A similar anomaly is reported by Wolff (1994) and Islam (1995). Moreover, the labor share of the primary sector now survives the introduction of the external debt ratio into the regression, and renders the Africa dummy insignificant everywhere. The parameters on the labor share in primary production in our preferred panel regressions, (3a) and (5a), are about the same as in the cross-section analysis (Table 1). The share of primary exports in total exports has a smaller and less significant effect on growth than the primary labor share, presumably because the former is a less satisfactory proxy for human capital than the latter. This leads us to conclude that our main results are quite robust: the size of the primary sector matters for growth.

4 Conclusions

We have found a statistically significant relationship between the size of the primary sector and the average rate of growth of output across countries. This effect appears to diminsh the importance of the relationship between education variables and growth: the effects of schooling generally drop in size and significance, when primary employment or primary exports are added to the regressions.

We can draw two possible conclusions from the empirical relationship between growth, the size of the primary sector, and school enrolment. First, it is possible that a large primary sector–based, for example, on an abundant natural resource–inhibits the creation of a (human-capital generating) secondary sector through its effect on the real exchange rate, thereby reducing the need for formal education as measured by the school enrolment rates. Second, it is also possible that a bad system of education inhibits the secondary sector by raising training costs. The continued dominance of the primary sector then further suppresses the secondary sector through the Dutch disease. These two possibilities are not mutually exclusive.

Of course, the statistical relationship between growth and primary employment and exports could result from a mechanism not involving human capital. In particular, it is possible that a productive primary sector could affect wages in the secondary sector by offering high wages to its own workers.[23] Efficiency wage theories would predict that wages be a positive function of

[23] Paldam (1994) has described the Dutch disease in Greenland along these lines.

industry productivity–as well as its expected rate of growth.[24] Other industries, however, paying lower wages than the primary sector and hence possibly facing high quit rates as workers leave for the lucrative primary sector, may be induced to offer similarly high wages to combat quits. This may deter hiring, learning, and growth.

[24]See Orszag and Zoega (1997).

References

[1] Arulampalam, W., and A. L. Booth (1996), "Who Gets Over the Training Hurdle? A Study of the Training Experiences of Young Men and Women in Britain," CEPR Discussion Paper No. 1470.

[2] Barro, R. J. (1991), "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics*, 106, 407-443.

[3] Barro, R. J. and J. W. Lee (1993), "International Comparisons of Educational Attainment," *Journal of Monetary Economics*, 32, 363-394.

[4] Barro, R., and X. Sala-i-Martin (1995), *Economic Growth*, McGraw-Hill, New York.

[5] Booth, A., and G. Zoega (1994), "Quitting Externalities, Excessive Layoffs and Firing Costs," CEPR Discussion Paper No. 1101.

[6] Bruno, M., and W. Easterly (1995), "Inflation Crises and Long-Run Growth," The World Bank, Washington, D.C., manuscript.

[7] Bruno, M., and J. Sachs (1982), "Energy and Resource Allocation: A Dynamic Model of the 'Dutch Disease', *Review of Economic Studies*, 49, 845-859.

[8] Buiter, W.H., and D. Purvis (1981), "Oil, Disinflation, and Export Competitiveness: A Model of the 'Dutch Disease'," in j. Ghandari, and B. Putnam (eds.), *The International Transmission of Economic Disturbances under Flexible Exchange Rates*, MIT Press, Cambridge, MA.

[9] Calvo, G. (1979), "Quasi-Walrasian Models of Unemployment," *American Economic Review*, 69, 102-107.

[10] Corden, W. M. (1984), "Booming Sector and Dutch Disease Economics: Survey and Consolidation," *Oxford Economic Papers*, 36, 359-380.

[11] Corden, W. M., and P. Neary (1980), "Booming Sector and De-Industrialization in a Small Open Economy," *Economic Journal*, 92, 825-848.

[12] Dixit, A. K., and R. S. Pindyck (1994), *Investment under Uncertainty*, Princeton University Press, Princeton, NJ.

[13] Edwards, S. (1992), "Trade Orientation, Distortions, and Growth in Developing Countries," *Journal of Development Economics*, 39, 31-57.

[14] Edwards, S. (1993), "Openness, Trade Liberalization, and Growth in Developing Countries," *Journal of Economic Literature,* 31, 1358-1393.

[15] Fischer, S. (1991), "Growth, Macroeconomics, and Development," NBER *Macroeconomics Annual* 1991, 329-364.

[16] Fischer, S. (1993), "The Role of Macroeconomic Factors in Growth," *Journal of Monetary Economics*, December, 485-512.

[17] Freeman, R. B. (1980), "The Exit-voice Tradeoff in the Labor Market: Unionism, Job Tenure, Quits, and Separations," *Quarterly Journal of Economics*, October, 643-673.

[18] Gylfason, T., and T. T. Herbertsson (1996), "Does Inflation Matter for Growth?," CEPR Discussion Paper No. 1503.

[19] Gylfason, T. (1997), "Exports, Inflation, and Growth," IMF Working Paper 97/xx (forthcoming).

[20] Herbertsson, T. T., and A. Sörensen (1996), "Policy Rules for Exploitation of Renewable Resources: A Macroeconomic Perspective," *Journal of Environmental and Resource Economics* (forthcoming).

[21] Hirschman, A. O. (1958), *The Strategy of Economic Development*, New Haven CT: Yale University Press.

[22] Huber, P. J. (1973), "Robust Regression: Asymptotics, Conjectures and Monte Carlo," *Annals of Statistics* 1, 799-821.

[23] Islam, N. (1995), "Growth Empirics: A Panel Data Approach," *Quarterly Journal of Economics*, 90, November, 1127-1170.

[24] Lane, P. R., and A. Tornell (1996), "Power, Growth and the Voracity Effect," *Journal of Economic Growth,* 1, 213-241.

[25] Levine, R., and D. Renelt (1992), "A Sensitivity Analysis of Cross-Country Growth Regressions," *American Economic Review*, 82, September, 942-963.

[26] Lewis, W. A. (1955), *The Theory of Economic Growth*, George Allen and Unwin, London.

[27] Lewis, W. A. (1968), *Some Aspects of Economic Development*, Ghana Publishing Corporation, Accra and Tema.

[28] Lucas, R. E. (1988), "On the Mechanics of Economic Development," *Journal of Monetary Economics* 22, July, 3-42.

[29] Mankiw, N. G., D. Romer, and D. N. Weil (1992), "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, 107, May, 407-437.

[30] Mauro, P. (1995), " Corruption and Growth," *Quarterly Journal of Economics*, 110, August, 681-712.

[31] Mincer, J., and Y. Higuchi (1988), "Wage Structures and Labor Turnover in the United States and Japan," *Journal of the Japanese and International Economies*, 2, 97-113.

[32] Nelson, R., and E. S. Phelps (1966), "Investment in Humans, Technological Diffusion, and Economic Growth," *American Economic Review*, 56, 69-75.

[33] Nerlove, M. (1996), "Growth Rate Convergence, Fact or Artifact? An Essay in Panel Data Econometrics," manuscript.

[34] Newbery, D. and J. E. Stiglitz (1983), *Theory of Commodity Price Stabilization*, Oxford University Press, Oxford.

[35] Orszag, J.M., and G. Zoega (1997), "Wages ahead of Demand," *Economics Letters* (forthcoming).

[36] Paldam, M. (1994), *Grönlands ökonomiske udvikling*, (The Economic Development of Greenland), Aarhus Universitetsforlag, Aarhus.

[37] Persson, T., and G. Tabellini (1994), "Is Inequality Harmful for Growth?," *American Economic Review*, 84, June, 600-621.

[38] Prais, S. J. (1995), *Productivity, Education and Training: An International Perspective*, National Institute of Economic and Social Research, Occasional Paper XLVIII, Cambridge University Press.

[39] Romer, P. M. (1986), "Increasing Returns and Long-Run Growth," *Journal of Political Economy,* 94, October, 1002-1037.

[40] Romer, P. M. (1990), "Endogenous Technological Change," *Journal of Political Economy,* 98, 5, S71-S102.

[41] Sachs, J. D., and A. M. Warner (1995), "Natural Resource Abundance and Economic Growth," *NBER Working Paper,* No. 5398, December.

[42] Salop, S. (1979), "A Model of the Natural Rate of Unemployment," *American Economic Review,* 69, 117-125.

[43] Stevens, M. (1994), "A Theoretical Model of On-the-job Training with Imperfect Competition," *Oxford Economic Papers,* 46, 537-562.

[44] Stevens, M. (1996), "Transferable Training and Poaching Externalities," in A. Booth and D. Snower (eds.), *Acquiring Skills,* Cambridge University Press.

[45] Wolff, E. (1994), "Human Capital Investment and Economic Growth: Exploring the Macro-Links," in Christopher F. B. and D. J. Soloff (eds.), *Human Capital Investment and Economic Performance: Multi-Disciplinary Perspectives and International Evidence,* Russel Sage Press (forthcoming).

5 Appendix A. The Data

We use data from the World Data Bank and the Penn World Tables. The data cover the period 1960-1992. The variables are:

- **Growth of GDP:** The RGDPCH (real GDP per capita at 1985 international prices, chain index) is taken from the Penn World Tables. This is an average, given by the formula $\frac{1}{T}\sum_{t=1}^{T}(log(GDP_t) - log(GDP_{t-1}))$ where T is the number of observations. T is at least 25 observations in the cross-section analysis, but 5 observations in the panel analysis.

- **Initial GDP:** Here we use RGDPCH from the Penn World Tables as defined above. GDP_0 is the observation in the initial year.

- **Investment:** This is an average for the period 1960-1992 of the real gross domestic investment, private and public, in proportion to GDP. These data come from the Penn World Tables. At least 25 observations are in each average in the cross-section analysis. In the panel model this is a five-year average.

- **Initial school enrolment:** Here we use World Bank data. Since no data are available for school enrolment before 1965, that year was used as the initial year in the cross-section analysis. In the panel analysis corresponding initial values for each subperiod were used. The primary enrolment rate is measured by gross enrolment of students at the primary level as a percentage of school-age children as defined by each country and reported to UNESCO. For some countries with universal primary education, the gross enrolment ratios may exceed 100 percent, because some pupils are below or above the local primary school age. Secondary enrolment rate is the gross enrolment of students at the secondary level as a percentage of school-age children as defined by each country and reported to UNESCO. Late entry of more mature students as well as repetition and "bunching" in the final grade can influence these ratios.

- **Labor in primary sector:** This is the labor force in farming, forestry, hunting, and fishing as a percentage of total labor force in the cross-section analysis in the year 1965. The data come from the World Data Bank.

- **Export of primary products**: This is the combined export of fuel and nonfuel primary products, as a percentage of total exports of goods and services in 1970. All data are from the World Bank. Exports of fuels comprise commodities in SITC Revision 1, Section 3 (Mineral Fuels and Lubricants and related materials). Exports of nonfuel primary products comprise commodities in SITC Revision 1, Section 0, 1, 2, 4 and Division 68 (food and live animals, beverages and tobacco, inedible crude materials, oils, fats, waxes, and nonferrous metals). The export figures are in current U.S. dollars. The figures are dollar values converted from domestic currencies using single-year official exchange rates. For a few countries, where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used. In the panel analysis the years 1970, 1975, 1980, 1985, and 1990 were used for each five-year period.

- **External debt:** This is an average for the period 1960-1992 of foreign debt divided by GDP at market prices in the cross-section analysis. Foreign debt consists of the outstanding stock or recognized direct liabilities of the government to the rest of the world, generated in the past and scheduled to be extinguished by government operations in the future or to continue as perpetual debt. Often there were very few observations for each country. GDP measures the total output of goods and services for final use occurring within the domestic territory of a given country, regardless of its allocation to domestic and foreign uses. GDP at a purchaser values (market prices) is the sum of GDP at factor cost and indirect taxes less subsidies. Both of these variables are reported in the World Data Bank. At least three observations were included in each five-year average in the panel analysis.

- **Exchange rate volatility:** This was defined as the variance of the logarithm of exchange rate divided by the GDP deflator for the period 1960-1992. The exchange rate, which is relative to the US dollar, is reported in the Penn World Tables. The GDP deflator is derived by dividing current-price estimates of GDP at market prices by constant-price estimates. This variable is reported in the World Bank Data. At least 16 observations are used for each average in the cross-section analysis.

TABLE 1. *Cross-Section Results*

	Dependent Variable: Per Capita Growth Rate, 1960-1992													
	(1)	(2)	(3*a*)	(4*a*)	(5*a*)	(3*b*)	(4*b*)	(5*b*)	(6*a*)	(7*a*)	(8*a*)	(6*b*)	(7*b*)	(8*b*)
Initial GDP	-0.008	-0.010	-0.014	-0.016	-0.016	-0.009	-0.011	-0.011	-0.013	-0.016	-0.016	-0.009	-0.012	-0.012
	(-4.28)	(-4.54)	(-5.44)	(-4.09)	(-4.03)	(-3.58)	(-2.58)	(-2.53)	(-5.62)	(-4.34)	(-4.31)	(-4.04)	(-4.08)	(-3.98)
Investment	0.152	0.120	0.110	0.146	0.145	0.122	0.149	0.149	0.121	0.149	0.149	0.137	0.155	0.155
	(8.41)	(5.11)	(4.47)	(4.39)	(4.29)	(4.24)	(3.86)	(3.80)	(6.08)	(5.16)	(5.11)	(5.47)	(4.94)	(4.88)
Primary education 1965	-	0.015	0.011	0.006*	0.007*	0.014	0.012*	0.012*	-	-	-	-	-	-
		(3.11)	(2.03)	(0.72)	(0.74)	(2.25)	(1.13)	(1.11)						
Secondary education 1965	-	0.010*	0.002*	0.005*	0.005*	-0.006*	-0.010*	-0.010*	-	-	-	-	-	-
		(1.08)	(0.24)	(0.36)	(0.36)	(-0.50)	(-0.60)	(-0.60)						
Labor in primary sector 1965	-	-	-0.024	-0.019*	-0.019*	-	-	-	-0.030	-0.023	-0.023	-	-	-
			(-2.54)	(-1.48)	(-1.46)				(-3.49)	(-1.91)	(-1.89)			
Export of primary products 1970	-	-	-	-	-	-0.020	-0.021	-0.021	-	-	-	-0.019	-0.020	-0.020
						(-3.44)	(-2.58)	(-2.54)				(-3.32)	(-2.60)	(-2.57)
External debt	-	-	-	-0.019	-0.018	-	-0.026	-0.026	-	-0.019	-0.019	-	-0.030	-0.030
				(-2.87)	(-2.70)		(-2.69)	(-2.58)		(-3.29)	(-3.14)		(-3.28)	(-3.18)
Exchange rate volatility	-	-	-	-	0.003*	-	-	0.000*	-	-	0.004*	-	-	-0.001*
					(0.30)			(0.00)			(0.38)			(-0.11)
Constant	0.054	0.063	0.105	0.124	0.125	0.073	0.087	0.087	0.113	0.127	0.127	0.077	0.101	0.101
	(4.13)	(4.47)	(4.72)	(3.67)	(3.66)	(3.83)	(2.84)	(2.80)	(5.33)	(4.09)	(4.08)	(4.49)	(4.40)	(4.35)
Africa dummy	-0.010	-0.007	-0.005	-0.003*	-0.003*	-0.008	-0.001*	-0.001*	-0.007	-0.004*	-0.004*	-0.010	-0.002*	-0.002*
	(-3.14)	(-2.40)	(-1.69)	(-0.55)	(-0.57)	(-2.07)	(-0.21)	(-0.21)	(-2.12)	(-0.89)	(-0.90)	(-2.56)	(-0.34)	(-0.32)
SE	0.013	0.012	0.012	0.013	0.013	0.012	0.012	0.012	0.012	0.013	0.013	0.012	0.012	0.012
$\overline{R}^2$	0.46	0.49	0.51	0.49	0.48	0.52	0.56	0.54	0.50	0.53	0.48	0.68	0.56	0.55
DF	121	109	107	57	56	79	41	40	113	61	60	82	44	43

Note: t-values appear within parentheses below the coefficients. *Not significant at the 5 per cent level in a one-tail test. The cut-off point for the h_0 is 2.33 at the 1 per cent level, 1.64 in a 5 per cent test, and 1.28 in a 10 per cent test.

TABLE 2. *Partial Correlation Between Per Capita Growth and Regressors*

	Investment rate	Primary education	Secondary education	Labor share in primary sector	Share of primary exports	External debt	Exchange rate volatility
With schooling	0.50	0.10*	0.05*	-0.19*	-0.36	-0.34	0.04*
$h_0 : r = 0$	(4.58)	(0.80)	(0.40)	(-1.54)	(-2.67)	(-2.87)	(0.33)
Without shooling	0.55	-	-	-0.24	-0.36	-0.37	0.05*
$h_0 : r = 0$	(5.31)	-	-	(-1.99)	(-2.67)	(-3.21)	(0.40)

Note: t-values appear within parentheses below the correlation coefficients. *Not significant at the 5 per cent level in a one-tail test. The cut-off point for the h_0 is 2.33 at the 1 per cent level, 1.64 in a 5 per cent test, and 1.28 in a 10 per cent test.

TABLE 3. *Panel Results, Five-year Intervals,* 1960-1992

	Dependent Variable: Per Capita Growth Rate									
	(1)	(2)	(3*a*)	(4*a*)	(3*b*)	(4*b*)	(5*a*)	(6*a*)	(5*b*)	(6*b*)
Initial GDP	-0.007	-0.009	-0.013	-0.058	-0.009	-0.023	-0.010	-0.038	-0.009	-0.017
	(-4.66)	(-4.27)	(-3.33)	(-5.29)	(-3.35)	(-3.59)	(-2.98)	(-4.05)	(-3.79)	(-3.71)
Investment	0.164	0.164	0.128	0.212	0.169	0.18	0.133	0.266	0.188	0.24
	(10.0)	(7.84)	(4.89)	(3.55)	(5.53)	(3.37)	(5.65)	(4.83)	(7.01)	(5.44)
Primary education	-	0.012	0.035	0.041	0.021	0.038	-	-	-	-
		(1.69)	(4.24)	(2.20)	(1.97)	(1.69)				
Secondary education	-	-0.017*	-0.044*	-0.008*	-0.025*	0.003*	-	-	-	-
		(-2.44)	(-4.38)	(-0.43)	(-2.77)	(-0.20)				
Labor in primary sector	-	-	-0.022*	-0.099	-	-	-0.021	-0.065	-	-
			(-1.47)	(-2.58)			(-1.73)	(-2.20)		
Export of primary products	-	-	-	-	-0.015	-0.007*	-	-	-0.009*	-0.013*
					(-1.79)	(-0.50)			(-1.24)	(-1.02)
External debt	-	-	-	-0.051	-	-0.045	-	-0.077	-	-0.030
				(-1.65)		(-2.84)		(-2.72)		(-2.54)
Constant	0.046	0.054	0.111	0.476	0.06	0.157	0.095	0.311	0.06	0.130
	(4.31)	(3.76)	(3.01)	(4.93)	(2.85)	(3.08)	(3.04)	(3.81)	(3.13)	(3.39)
Africa dummy	-0.002*	-0.001*	-0.005*	0.000*	-0.003*	-0.002*	0.004*	0.004*	0.001*	0.000*
	(-0.87)	(-0.34)	(-1.45)	(0.06)	(-0.76)	(-0.34)	(-0.98)	(0.53)	(0.33)	(0.02)
SE	0.032	0.030	0.025	0.017	0.030	0.024	0.031	0.025	0.030	0.249
$\overline{R}^2$	0.11	0.11	0.17	0.37	0.12	0.21	0.11	0.26	0.10	0.19
DF	856	535	268	54	311	100	353	81	429	158

Note: t-values appear within parentheses below the coefficients. *Not significant at the 5 per cent level in a one-tail test. The cut-off point for the h_0 is 2.33 at the 1 per cent level, 1.64 in a 5 per cent test, and 1.28 in a 10 per cent test.

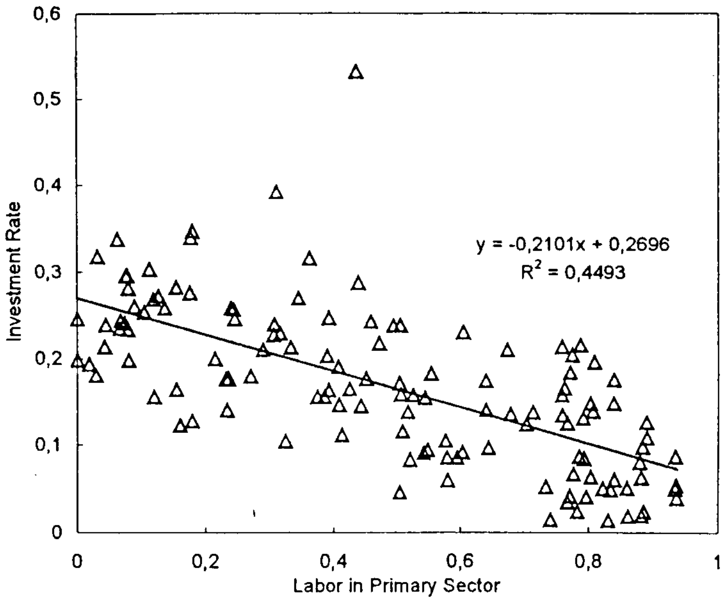

FIGURE 1. *The Relationship Between Investment share of labor Primary Sector in a Cross Section of Countries*

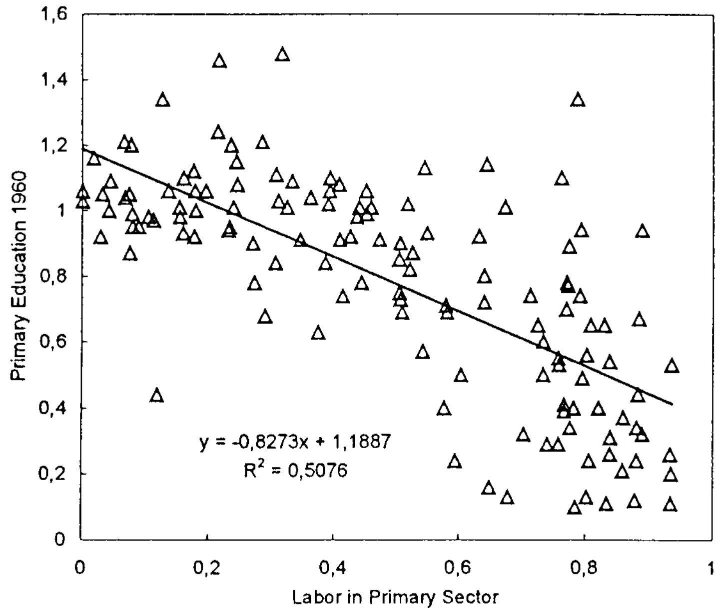

FIGURE 2. *The Relationship Between Primary School Enrolment* 1960 *and Share of Labor in Primary Sector in a Cross Section of Countries*

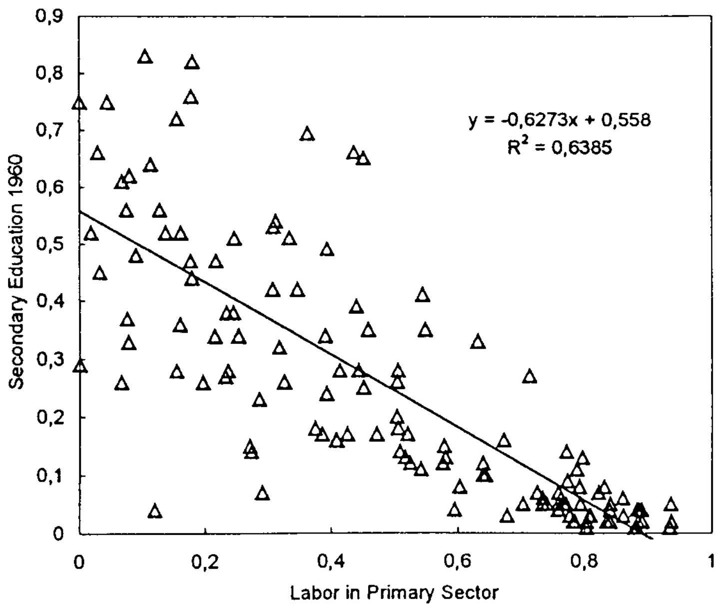

FIGURE 3. *The Relationship Between Secondary School Enrolment* 1960 *and Share of Labor in Primary Sector in a Cross Section of Countries*

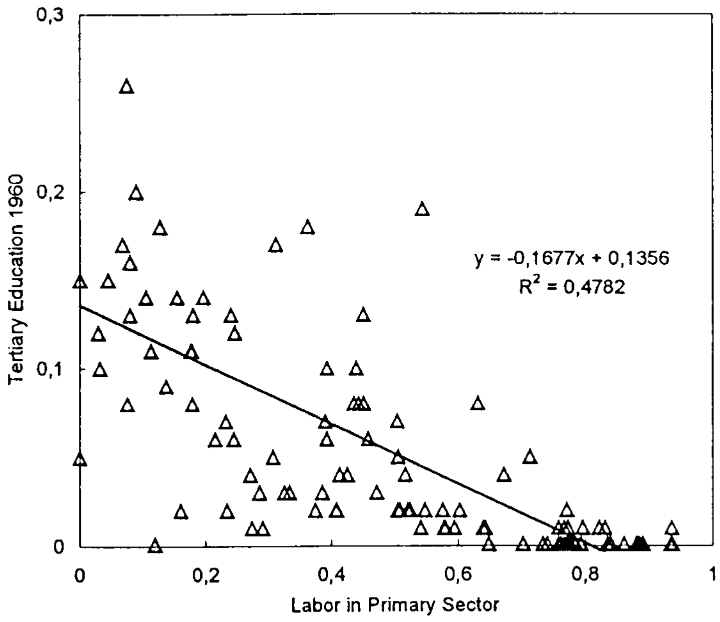

FIGURE 4. *The Relationship Between Tertiary School Enrolment* 1960 *and Share of Labor in Primary Sector in a Cross Section of Countries*