Terms of Trade and Economic Growth in a World of Constrained Capital Mobility

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Summary:

This paper focuses on the interaction between world community and capital markets within the framework of an extended neoclassical growth model. The model incorporates raw materials as an essential input and captures the observed, but hitherto unexplained impact of terms of trade on economic growth. It is shown that in a world of declining real prices of industrial raw materials, the steady state growth rate is an increasing function of the input ratio raw materials/unskilled labour. When international capital flows are constrained, the speed of convergence is determined by the same variables.

Sammendrag:

Interaksjonen mellom internasjonale råvaremarkeder og den internasjonale kapitalmarknaden blir analysert innanfor ramma av nyklassisk vekstmodell. I modellen inngår råvarer som essensielle innsatsvarer i produksjonen. Modellen viser korleis bytteforholdet påverkar den økonomiske veksten. Råvareimportørar som opplever forbetring av bytteforholdet vil ha høgare vekst i "steady state" jo større del av innsatsfaktorane råvarer utgjer relativt til ukvalifisert arbeidskraft. Dersom den internasjonale kapitalmarknaden er imperfekt, vil også konvergeringsraten avhenga positivt av forholdet råvarer/ukvalifisert arbeidskraft.

Indexing terms:

Economic growth
Capital mobility
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Terms of trade
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Råvarer

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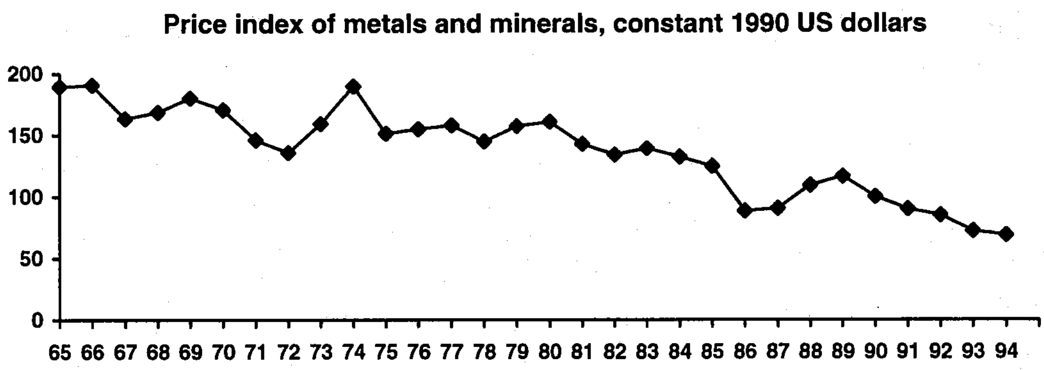
Contents

1. Introduction

Empirical work on the determinants of growth has found that changes in terms of trade have a significantly positive impact on economic growth (Barro and Sala-i-Martin 1995). This relationship has, however, not been captured by theoretical growth models. To the contrary, as observed by Barro (1996), changes in terms of trade should not affect real GDP growth unless it stimulates employment. This paper develops a model which entails a channel through which terms of trade affect economic growth. A precondition for the presence of a relationship between terms of trade and growth is the existence of a long-run trend in terms of trade. Such a trend is most clearly seen between non-oil commodity-exporting countries and the industrialized countries since the 1960s as shown in figure 1.[1]

Figure 1



Source: World Bank 1994

This paper focuses on the impact of this trend on countries who use imported raw materials as inputs in industrial production and export manufactured goods. It extends

[1] There has been some controversy over the development in real commodity prices. The Hotelling rule states that the real price of exhaustible natural resources will increase at a rate equal to the real interest rate over time, while the Prebish - Singer hypothesis asserts that commodity prices are on a long-term declining trend. Recent empirical evidence (Cuddington 1992) supports neither theory but finds that out of 26 commodities analyzed, 5 exhibited a positive price trend during the period 1900-1983, 5 had a negative trend, and the remaining 16 were trendless.

the neoclassical growth model by the inclusion of industrial raw materials as essential inputs in the production function. Earlier work on the oil price shocks in the 1970s and 1980s emphasized the role that international capital markets played in absorbing the shocks and redistributing world income (Bruno and Sachs 1985, Christini 1995). Therefore, in order to capture the long-run relationship between world commodity and capital markets, the production function also entails two classes of capital distinguished by the degree of international mobility. This setting provides a framework for analyzing how world commodity- and capital markets interact with local investment to generate economic growth, and engenders additional insight as to why growth rates differ among countries. It finally contributes to a better understanding of why capital does not flow to labor-abundant developing countries to the extent predicted by the standard neoclassical growth model.

I show that the declining price trend depicted in figure 1 has the same impact on economic growth as has labor-augmenting technological progress. Further, it is shown that the steady state growth rate is determined by the relative importance of raw materials as compared to raw labor in the production process. The larger the ratio of raw materials to raw labor, the higher the growth rate in a situation with declining raw materials prices. This ratio varies among countries and is a function of industrial structure and technology.

The interaction between world capital and commodity markets works as follows: Declining real costs of raw materials improve the productivity of all other factors of production, and more so the higher the raw materials to raw labor ratio. Therefore, capital would flow from less raw materials intensive countries to more raw materials intensive countries in a world of perfectly mobile capital. With constrained capital mobility, capital flows are restricted by local investment in immobile capital. The model predicts that the fastest-growing countries in the world are relatively raw materials intensive, open to international capital flows and have a high investment rate in immobile capital such as human capital and various forms of infrastructure. It also helps to be a net importer of raw materials, although the net gains from declining prices of raw materials may be positive for net commodity exporting countries also, if they have a relatively resource-intensive industrial structure and declining relative prices reflects declining relative costs in the extractive and basic processing industries.

The rest of the paper is organized as follows: Section 2 briefly review related research, while section 3 presents the Ramsey growth model. The simplest version for an economy closed to international capital flows is discussed in section 3.1 and an extension with constrained international capital flows is laid out in section 3.2. Some empirical evidence is presented in section 4, and section 5 concludes.

2. Relations to previous research

The interrelationship between commodity prices and economic activity has previously been analyzed by Bruno and Sachs (1985) and Christini (1995). Both contributions focused on the impact of a commodity price shock on world real output and employment and both emphasized the role of world capital markets as a transmitter and absorber of the price shock. Bruno and Sachs (1985) allowed commodity prices to influence output through two channels. First, changes in commodity prices shift the factor price frontier in a similar way as Hicks-neutral technological change. Second, commodity prices affect demand through real wages, employment and the world distribution of wealth. Christini (1995) focused on demand effects only. I incorporate the insights from Bruno and Sachs (1985) into a neoclassical growth framework and analyze how industrial structure, represented by the intensity of raw materials use, affects steady state growth as well as the transitionary dynamics.

Raw materials and energy are routinely incorporated into macro-economic forecasting and business cycle models, but are absent from growth models. There is, however a growing literature on the role of intermediate inputs in growth and development, focusing either on productivity gains from increased specialization through an expanding variety of inputs (Romer 1987) or improvements of the quality of inputs (Grossman and Helpman 1991 ch. 4). In these models intermediate inputs are the vehicle for technological progress. Raw materials differ from such intermediate inputs in three important ways. First, they are homogeneous and standardized and are not seen as carriers of new technology. Second, they are internationally tradable, while access to a limited range of specialized intermediate products has often been stated as a cause of poverty traps in growth models.[2] Third, they are to a large extent provided by nature. Therefore, raw materials have more in common with raw or unskilled labor than differentiated intermediate inputs, and are accordingly lumped together with labor into a composite non-accumulated factor of production in the

[2] Recent contributions are Rodrik (1996), and Rodriguez-Clare (1996).

model developed in this paper. In this regard the model can be seen as a first step towards integrating business cycle and growth models as far as treatment of raw materials is concerned.

A growth model with constrained capital mobility was developed by Barro, Mankiw and Sala-i-Martin (1995). The innovation of this paper is to combine their model with a composite non-accumulated factor of production consisting of unskilled labor and industrial raw materials into a two level Cobb Douglas production function. Within this framework the dynamic interaction between international commodity- and capital markets in a world of constrained capital mobility is analyzed.

3. The Ramsey model

The setting is a Ramsey growth model for a small, open economy. The production function is a two-level nested Cobb-Douglas function, as the special case of a two-level nested CES function. At the first level the production function contains two inputs, non-accumulated factors, denoted N, and accumulated factors, denoted D. At the second level, non-accumulated factors are split into labor and raw materials, while accumulated factors are split into mobile and immobile capital. Consequently, each composite consists of one internationally mobile and one immobile factor of production as raw labor is considered internationally immobile. The production function is given by:

$$Y = AN^{1-\alpha}D^{\alpha} \tag{1}$$

Where Y is gross output and A is the level of technology. In intensive form the production function reads:[3]

$$\hat{y} = A\hat{d}^{\alpha} \tag{1'}$$

where $\hat{y}$ is output per unit of non-accumulated factors and $\hat{d}$ is the ratio of accumulated to non-accumulated factors of production. Income generated can be spent on consumer goods or saved. The allocation between consumption and savings is determined by the consumers' utility maximization problem. Infinitely lived households maximize the standard constant intertemporal elasticity of substitution utility function:

$$u(c) = \int_{t}^{\infty} \frac{c^{1-\theta} - 1}{1-\theta} e^{-\rho t} dt \tag{2}$$

where c is consumption per capita, ρ is the time preference rate and θ is the elasticity of marginal utility. It is assumed that households hold assets in the form of claims on capital. In addition each person supplies inelastically one unit of labor services per unit of time, while a quantity of raw materials per unit of time corresponding to demand at the exogenously determined average price during that unit of time is imported. For convenience it is assumed that the population and the labor force remain constant. The equilibrium capital accumulation trajectory together with the

[3] Lower case letters refer to variables in per capita units while lower case letters with a hat refer to variables measured in units of non-accumulated factors throughout the paper.

equilibrium growth path of income and consumption are found through the usual procedure where consumers maximize utility and firms maximize profits, subject to a set of constraints. Let us start with the consumer. She maximizes utility as given by equation (2) subject to the flow household budget constraint:

$$\dot{a} = ra + w - c \tag{3}$$

where a is the stock of assets per capita, r is the rate of return on savings, w is the wage rate. The utility maximization problem can be solved by means of the present value Hamiltonian:

$$J = \frac{c^{1-\theta} - 1}{1-\theta} e^{-\rho t} + v[ra + w - c] \tag{4}$$

From the first-order conditions we get the optimal consumption path:

$$\frac{\dot{c}}{c} = \frac{1}{\theta}(r - \rho) \tag{5}$$

which is the standard Euler equation of Ramsey growth models. The equilibrium rate of interest depends on the structure of the capital market, and is derived for each case in the subsections below.

3.1 The Ramsey model with no international capital flows

In this subsection the aggregate accumulated capital input, D, is treated as one homogeneous input, while the non-accumulated composite of labor and raw materials is given by:

$$N = L^{1-\beta} Q^{\beta} \tag{6}$$

where L is labor and Q is raw materials. Plugging this into the production function (1) yields:

$$Y = A\left(L^{1-\beta} Q^{\beta}\right)^{1-\alpha} D^{\alpha} \tag{1a}$$

In intensive form (1') still applies. Firms maximize present value profits, which reduces to maximizing profits in each period of time in the absence of adjustment costs. Profits are given by:

$$\pi = A(L^{1-\beta} Q^{\beta})^{1-\alpha} D^{\alpha} - (r_d + \delta)D - wL - P_q Q \tag{7}$$

where δ is the depreciation rate of accumulated factors and r_d is the net rental rate on accumulated factors and P_q is the exogenously given price of natural resources measured in units of final output. Before proceeding with finding the equilibrium trajectory of this economy one important property of the model is observed:

Observation 1

Given the production function (1a), declining commodity prices have the same impact on aggregate output as has labor-augmenting technological progress.

To see this, note that demand for raw materials can be derived by maximizing profits with respect to Q. This yields the familiar demand schedule

$$Q = \beta(1-\alpha)Y / P_q \qquad (8)$$

Substituting back into (1a) gives:

$$Y = \tilde{A}\left(L^{1-\beta} P_q^{-\beta}\right)^{(1-\alpha)\varsigma} D^{\alpha\varsigma} \qquad (1b)$$

where $\tilde{A} = \left[A(\beta(1-\alpha)^{\beta(1-\alpha)}\right]^{1/(1-\beta(1-\alpha))}$ and $\varsigma = 1/(1-\beta(1-\alpha))$. Assume that P_q declines over time. Then (1b) has the form $Y(t) = F(A(t)L, K(t))$, which is the general production function with labor-augmenting technological progress.

In order to find the equilibrium growth path of the economy, it is useful to express the system in terms of variables that are constant in steady state. Observation 1 implies that non-accumulated factors have the same properties in the model as has "efficient labor" in standard neoclassical growth models. Therefore, the variables in terms of non-accumulated factor units are constant in steady state. With no international capital flows $a = d$ in equilibrium. Further, in equilibrium the rental rates or prices of inputs must equal their marginal products. Now, let P_q change at a constant, exogenous rate

η and recall that the labor force and population are assumed to be constant. From (8) we have that Q, and hence the ratio Q/L, grow at the rate $-\eta$ while N grows at the rate $-\beta\eta$. Then the profit equation (7) can be rearranged to read:

$$\pi = N\left(A\hat{d}^{\alpha} - (r_d + \delta)\hat{d} - w(Q/L)^{\beta} - P_q(Q/L)^{1-\beta}\right) \tag{7'}$$

At time t, the ratio $Q/L = (Q_0/L_0)e^{-\eta t}$, where we set $(Q_0/L_0) = \beta/(1-\beta)$. The first order conditions for profit maximizing read: $r_d = \alpha A\hat{d}^{\alpha-1} - \delta$, $w = (1-\alpha)(1-\beta)A\hat{d}^{\alpha}e^{-\beta\eta t}$ and $P_q q = \beta(1-\alpha)A\hat{d}^{\alpha}e^{-\beta\eta t}$. Substituting all this into the flow household budget constraint yields the overall economy resource constraint, which in turn determines the accumulation of capital per unit of non-accumulated factors:

$$\dot{\hat{d}} = (1-(1-\alpha)\beta)A\hat{d}^{\alpha} - \hat{c} - (\delta - \beta\eta)\hat{d} \tag{9}$$

where we have subtracted the share of gross output paid to foreign suppliers of raw materials. Finally, inserting the equilibrium rental rate of capital into the Euler equation and using the condition that $\hat{c} = C/N = ce^{\beta\eta}$, we have that

$$\frac{\dot{\hat{c}}}{\hat{c}} = \frac{\dot{c}}{c} + \beta\eta = \frac{1}{\theta}\left((1-(1-\alpha)\beta)\alpha A\hat{d}^{\alpha-1} - \delta - \rho + \theta\beta\eta\right) \tag{10}$$

In steady state $\dot{\hat{y}} / \hat{y} = \dot{\hat{c}} / \hat{c} = \alpha(\dot{\hat{d}} / \hat{d}) = 0$. Therefore, gross output and the stock of accumulated factors, both in per capita terms, grow at the rate $-\beta\eta$ and $-\beta\eta/\alpha$ respectively, which are positive constants as long as $\eta < 0$. If prices of raw materials should follow the Hotelling rule and increase at a rate r, on the other hand, we have a "limits to growth" scenario, where raw materials become increasingly scarce, and consequently output and consumption decline. These results are summarized as follows:

Result 1

In steady state

i) $\frac{\dot{y}}{y} = \frac{\dot{c}}{c} = -\beta\eta > 0$ *whenever* $\eta < 0$, ii) $\frac{\dot{d}}{d} = -\frac{\beta\eta}{\alpha} > 0$ *whenever* $\eta < 0$

Note that the only thing that matters for steady state growth in this setting is the composition of the non-accumulated production factor, that is the relative importance of raw materials compared to unskilled labor. If we allow the value of β to vary among countries, growth rates will differ too. An interpretation of this result is that countries grow faster in steady state the higher the share of raw materials intensive industries compared to (unskilled) labor-intensive industries in total output. It also suggests that countries grow faster the larger the share of goods-producing sectors in total output.

3.2 The model with international capital flows

Two modifications to the model are introduced in this section. First, the accumulated factor, D, is a composite of mobile capital denoted K, and immobile capital denoted H. Second, we allow for international capital flows, but only in mobile capital as the designation suggests. Internationally mobile capital earns the same rate of return in all countries, which is taken to be exogenous. The return to H-capital, on the other hand, may vary among countries. However, since investors always have the opportunity to invest abroad, the expected return to new investments in H-capital can not be lower than that on K-capital. The capital composite is defined as:

$$D = H^{1-\gamma} K^{\gamma} \tag{11}$$

Plugging this into the production function (1) yields

$$Y = AN^{1-\alpha}\left(H^{1-\gamma} K^{\gamma}\right)^{\alpha} \tag{1b}$$

The stock of K-capital employed in any economy is determined by the condition that its marginal product equals the world interest rate at every point in time. K-capital employed is thus not restricted by domestic savings, and is given by:

$$K = \frac{\gamma\alpha}{r+\delta} Y \tag{12}$$

where r is the exogenous international rate of interest. Clearly, the K-capital/ output ratio is constant over time whether the economy is in steady state or not. Plugging (12) back into the production function (1b) yields $Y = \overline{A}N^{(1-\alpha)/(1-\alpha\gamma)}H^{\alpha(1-\gamma)/(1-\alpha\gamma)}$, or in intensive form:

$$\hat{y} = \overline{A}\hat{h}^{\varepsilon} \qquad (1b')$$

where $\overline{A}$ is a constant defined by $\overline{A} = \left(A(\alpha\gamma / r)^{\alpha\gamma}\right)^{1/1-\alpha\gamma} >$ A, and $\varepsilon = \alpha(1-\gamma)/(1-\alpha\gamma) < \alpha$ Note that output is now a function of the ratio of H-capital to non-accumulated factors only. To determine accumulation of H-capital, we again turn to the consumer and her utility maximization problem. She now maximizes (2) subject to the flow household budget constraint broken down as follows:

$$\dot{h} + \sigma\dot{k} + \dot{\sigma}k = r_h h + r\sigma k + w - c \qquad (13)$$

where σ is the share of K-capital owned by domestic citizens. Whenever $r_h > r$, all domestic savings will be invested in H-capital, and $\sigma = 0$. In that case the constraint on foreign investment is binding. When $r_h = r$ on the other hand, domestic savings will be allocated among the two kinds of capital such that $h/k = (1-\gamma)/\gamma$, or invested abroad. In the following it will be assumed that initially $r_h > r$ and hence $\sigma = 0$ in developing countries, while $r_h = r$ in developed countries. It follows that the demarcation line between developed and developing countries is whether return to H-capital is higher than or equal to the world interest rate, or equivalently, whether the ratio h/k is lower than or equal to the ratio $(1-\gamma)/\gamma$. The resource-constraint for the representative household in a developing country then reads:

$$\dot{h} = r_h h + w - c \tag{13a}$$

The resource constraint for the economy as a whole in terms of units of non-accumulated factors is found by substituting the equilibrium factor prices into (13a) and maintaining the result from the previous section that the N aggregate grows at a rate $-\beta\eta > 0$ due to declining raw materials prices:

$$\dot{\hat{h}} = (1-(1-\alpha)\beta)(1-\alpha\gamma)\overline{A}\hat{h}^{\varepsilon} - \hat{c} - (\delta - \beta\eta)\hat{h} \tag{13b}$$

For convenience it is assumed that the depreciation rate is the same for H- and K-capital. Steady state consumption per unit of non-accumulated factors is now given by:

$$\frac{\dot{\hat{c}}}{\hat{c}} = \frac{\dot{c}}{c} + \beta\eta = \frac{1}{\theta}\Big((1-(1-\alpha)\beta)(1-\alpha\gamma)\varepsilon\overline{A}\hat{h}^{\varepsilon-1} - \delta - \rho + \theta\beta\eta\Big) \tag{14}$$

Again we have a steady state characterized by $\dot{\hat{c}} / \hat{c} = \dot{\hat{y}} / \hat{y} = \varepsilon(\dot{\hat{h}} / \hat{h}) = 0$, while per capita output grows at a rate $-\beta\eta$. Note that since there is a non-accumulated factor of production, this is not a model of endogenous growth in spite of the constant h/k ratio. Comparing (14) to (10) it is clear that the steady state growth trajectory is unaffected by whether capital is internationally mobile or not. What is interesting to developing countries, therefore, are the transitionary dynamics, to which we now turn.

3.2.1 Transitionary dynamics

Given that K is perfectly mobile and K and H are perfect substitutes as a store of value, we have that $r_h = r$ in steady state. The transition path is characterized by an increasing h/k ratio from an initial level below $(1-\gamma)/\gamma$, meaning that local investment in H-capital poses a constraint on net inflows of K-capital. As commodity prices decline, the marginal product of all other inputs increases and induces an instantaneous inflow of investment to restore equilibrium in the international capital market. In addition, as the marginal return to H-capital increases, local investors add to their stock as long as $r_h > r$, triggering a second wave of capital inflows.

The steady state levels of output per unit of non-accumulated factors are derived from equations (10) and (1') for the closed economy and (14) and (1b') for the open economy:

$$\hat{y}^*_{closed} = A^{1/(1-\alpha)}(\alpha / (\delta + \rho - \theta\beta\eta))^{\alpha/(1-\alpha)} \quad (15a)$$

$$\hat{y}^*_{open} = \bar{A}^{1/(1-\varepsilon)}((1-\alpha\gamma)\varepsilon / (\delta + \rho - \theta\beta\eta))^{\varepsilon/(1-\varepsilon)} \quad (15b)$$

These conditions imply that the steady state *level* of income per unit of non-accumulated factors, and consequently income per capita is lower the larger the share of raw materials in the non-accumulated factor composite as long as $\eta < 0$. Note also that for reasonable parameter values $\hat{y}^*_{closed} > \hat{y}^*_{open}$. To keep the analysis tractable, let us make the simplifying assumption that the savings rate remains constant during the transition period. Then, as shown by Barro and Sala-i-Martin (1995) the speed of convergence is given by:[4]

$$v_{closed} = (1-\alpha)(\delta - \beta\eta) \tag{16}$$

$$v_{open} = (1-\varepsilon)(\delta - \beta\eta) \tag{17}$$

As is well known, the open economy converges towards steady state faster than the closed economy, and consequently it converges faster the larger the share of K-capital in total accumulated factors, which in turn is reflected in a smaller ε. Further, the speed of convergence is faster the less capital intensive and the more raw materials intensive the technology, again provided that $\eta < 0$. Note that α and β are independent, such that an economy may be both raw materials intensive and capital-intensive, which in fact is often the case.[5] In other words, by our definition of a developed country, we have that a developing country becomes developed in a shorter period of time the more open it is towards foreign investment, and the more resource-intensive its technology. It does, however, become "developed" at a lower level of income. These results are summarized in result 2 and illustrated by figure 2.

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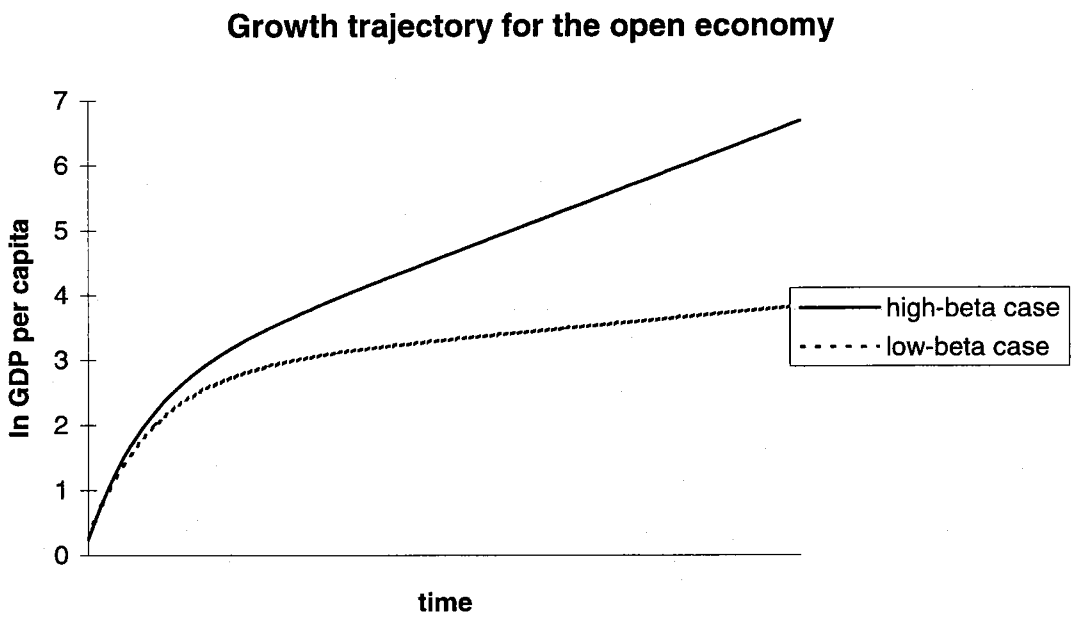
4 The restrictions imposed on parameters for a constant savings rate is $\theta = (\delta + \rho) / (\varepsilon\delta + \beta\eta(1-\varepsilon))$

5 See Nordås (1996) for a case study of the South African economy.

Figure 2



Result 2

When $\eta < 0$, $\hat{y}^*$ is lower and v faster the larger is β.

Figure 2 represents two developing countries starting out at the same initial level of output per capita and they are similar in all respects except for the value of β. The graphs are drawn from a linearized convergence trajectory where $\ln[y(t)] = e^{-vt} \ln y(0) + (1 - e^{-vt}) \ln(y^*)$, and $y = \hat{y}(\beta / (1-\beta))^{\beta} e^{-\eta t}$. The high-$\beta$ country embarks on a rapid convergence path, and reaches a steady state while the low-β country is still in its transitionary phase. For the parameter values applied in the figure, the steady state growth rate for the high-β country is above the growth rates during the transitionary period in the low-β country, such that the real income gap widens during the entire period.[6] For a trend decline of real commodity prices of 2

[6] The parameter values are $\alpha = 0.67$, β-high = 0.4, β-low = 0.1, $\gamma = 0.3$, $\theta = 3$, $\delta = 0.05$ $\rho = 0.02$.

percent annually, the transitionary period takes about 200 years for the high-β country, underscoring the importance of focusing on transitionary dynamics.

4. Some empirical evidence

4.1 Growth and resource intensity

The results in section 3 imply that real GDP growth depends on terms of trade. In this section the interrelationship between real prices of imported raw materials and real GDP is investigated empirically. Table 1 illustrates the importance of the cost of raw materials as a source of growth in some selected countries during the period 1970-92. Annual average changes in real P_q are taken to be the annual average change in P_q measured in local currency deflated by the local GDP deflator.[7] Calculating β is more problematic. While Q is taken to be the nominal value of imported metals and minerals (SITC code 27, 28, and 68) in local currency, it is more difficult to calculate the value of unskilled labor input since national accounts statistics do not include such figures. One possibility is to take the minimum wage rate, if any, times the total number of hours worked in the economy, and assume that compensation of employees in excess of this estimate represents return to human capital. Another alternative is to assume that the wage rate in agriculture represents the average compensation of unskilled labor and estimate L as average compensation per employee in agriculture times total employment in the economy. Again compensation of employees in excess

[7] Commodity prices are usually deflated by the manufacturing unit value index. However, since commodities are important inputs in the manufacturing process, the manufacturing unit value index is highly affected by the commodity price index. Therefore, to assess the impact of commodity prices on aggregate economic activity, the GDP deflator is the appropriate deflator.

of this is assumed to be return to human capital. In table 1 below the latter alternative is chosen due to availability of data.[8] The countries included in the table are all industrial raw materials importing countries. Apparently the value of β varies substantially among countries although it turns out that the value is fairly stable between 0.1 and 0.2 over time in the high-income OECD countries included. Except for the first two columns, all entries in the table are given as average annual percentage change over the period.

Table 1

Country	β 1970	β 1980	avg. η 1970-80 (percent change)	avg. η 1980-92 (percent change)	avg. $-\beta\eta$ 1970-80 (percent change)	avg. $-\beta\eta$ 1980-92 (percent change)	Growth GDP per capita, 1970-80	Growth GDP per capita 1980-92
Kenya	0.68	0.69	1.3	0.5	-0.9	-0.4	4.4	0.0
Japan	0.30	0.14	-2.1	-8.6	0.6	1.2	3.2	3.4
Korea	0.19	0.28	-1.9	-7.3	0.4	2.1	6.1	7.7
Taiwan	0.17	0.46	-0.7	-7.3	0.1	3.3	7.1	5.9
Denmark	0.12	0.12	-2.1	-6.5	0.3	0.8	1.6	1.8
Ireland	0.17	0.17	-1.6	-6.1	0.3	1.0	3.1	2.9

Before we go on to analyze these results, it is important to note that real local costs of raw materials depend on the real exchange rate and the cost of local inputs, which to a large extent mirror relative productivity growth. Therefore, countries which have experienced declining overall productivity over time, such as Kenya, have seen the real cost of raw materials rising in spite of the trend depicted in figure 1. Even with this qualification in mind, table 1 suggests that raw materials prices indeed contribute to different growth rates among countries

[8] For Taiwan, compensation of employees by sector is not available, therefore a proxy taking value added in agriculture times the average share of labor in value added for the entire economy is adopted. Sources for calculations are the following: Commodity prices: World Bank (1994), exchange rates and real GDP per capita measured in USD: Penn World Tables version 5.6, GDP deflator: IMF (1995), compensation of employees in agriculture: UN (1980 and 1989), employment in agriculture: OECD (1982) and World Bank (1995). Data for Taiwan: Taiwan Statistical Data Book 1994.

Korea and Taiwan represent resource-poor newly industrialized countries who have gained the most from declining costs of industrial raw materials. First, structural changes, possibly induced by changes in the relative marginal productivity of capital among sectors due to changes in relative input prices, have induced a sharp increase in β between 1970 and 1980, particularly as far as Taiwan is concerned. Second, the real cost of industrial raw materials has declined sharply, especially during the 1980s, inducing growth in per capita income to the tune of on average 2.1 and 3.3 percent during the 1980s for Korea and Taiwan respectively. In other words, if Korea and Taiwan were moving along a steady state growth trajectory during this period, GDP per capita would have grown by 2.1 and 3.3 percent annually in the absence of technological progress.

OECD countries like Denmark and Ireland have had a stable β since 1970 and declining real cost of industrial raw materials have generated moderate rates of per capita growth. Finally, Japan has developed from the Korea/Taiwan type economy with a relatively high value of β in 1970 to a typical OECD economy with a relatively low value of β during the period analyzed. Hence Japan has experienced similar gains as each of the two groups in the respective periods.

If these proxies for β are anywhere near the actual figures, it is clear that commodity prices have indeed been an important driving force for economic growth. Furthermore the results go some way in explaining how terms of trade are both significant and important in explaining growth through labor-augmenting cost reductions. Note finally that the ranking of countries according to actual growth and predicted growth by the model developed here is similar during the 1980s, when the impact of terms of trade seems to have been most profound.

4.2 Foreign direct investment and local investment in immobile capital

In this section empirical evidence for the complementarity between K- and H-capital emphasized in section 3.2 is sought. The model predicts that the net stock of foreign direct investment (FDI) is negatively correlated to the ratio k/h, and positively related to real changes in the relative price of imported intermediate goods. Data for the latter variable are not available, and changes in terms of trade (of all merchandise trade) turned out not to have a significant impact on net FDI. The stock of net FDI per unit of GDP was regressed on the ratio k/h, and a number of other variables thought to influence the stocks and flows of FDI. k is taken to be the stock of physical capital per capita owned by domestic citizens, while h is the stock of human capital as measured by the average number of years of schooling in total population over the age of 15. Since these two variables are not measured by the same unit of account, indices setting the value in the United States in 1985 = 100 are applied. It turned out that apart from k/h only the share of fuels, metals and minerals in total exports improved the adjusted R square while maintaining an F-value corresponding to a significance level below 5 percent. The results are shown in table 2 where t-statistics are in parentheses.[9]

[9] Other variables that did not improve the adjusted R square was the following: Openness as measured by the ratio total trade/GDP, black market premium on foreign exchange, dummies for Asia and Africa, 2*log GDP per capita, government share of GDP.

Table 2 **FDI per unit of GDP**

Intercept	k/h	share fuels, metals and minerals in exports	R^2	Number of observations
0.037 (2.45)	-0.0268 (-2.17)	0.0476 (1.835)	0.145	54

Sources: k: Penn World Table version 5.6, h: Barro and Lee (1993), share fuels etc.: World Bank (1987), net FDI: UN (1995)

The regression is run on a cross-section of data in 1985, applying OLS.[10] The significantly positive coefficient on the share of fuels, metals and minerals in exports is probably due to the dominance of multinational enterprises in the mineral sector (Dunning 1993). As expected, the coefficient on *k/h* is negative and significant. The overall explanatory power of the regression as measured by R^2 is relatively low. However, FDI was heavily regulated in most countries during the period of time of relevance to the regression. Furthermore, FDI is affected by a host of variables related to investor confidence not incorporated in the model. Therefore, a relatively low R^2 should be expected.

The theoretical as well as the empirical findings of this paper are related to De Long and Summers (1991 and 1993). They claim that accumulation of machinery and equipment, which is probably the most mobile category of capital, is the driving force behind economic growth while they find that the contribution of non-equipment investment to growth is at best minor. In contrast, the model developed here predicts that output is determined by accumulation of H-capital through equation (1b'), albeit

[10] 1985 is chosen for several reasons: this is he last year for which comprehensive data on human capital is available from Barro and Lee (1993), and it is the base year for constant international price estimates of all the variables in the Penn World tables version 5.6. Data given at current USD from other sources are therefore applied without any adjustments. The 54 countries included are those for which both data on capital stock are available in the Penn World Tables and data on average number of years of schooling are available from Barro and Lee (1993). Two outlayers, Zimbabwe and Panama, were taken out of the sample.

there is indeed a one to one relationship between accumulation of K-capital and output given by equation (12). The minor contribution from non-equipment investment in developing countries found in De Long and Summers (1993) can be explained if large (public) investments in human capital or infrastructure are accompanied by restrictions on international capital flows. This could envisage a situation where $h/k > (1-\gamma)/\gamma$, which implies that the return to H-capital would go below the international rate of return, and thus below its opportunity cost, while still improving the rate of return on K-capital.[11] Finally, other studies, all in industrialized OECD countries report a significantly positive impact of public investment in infrastructure on productivity in the private sector (Aschauer 1989; Munnell 1990; and Nadiri and Mamuenas 1994).

5. Summary and conclusions

This paper has analyzed the repercussions of a long-run trend of declining raw materials prices on commodity-importing countries' productivity and growth, by incorporating raw materials as an essential input in the production function. It is found that declining costs of raw materials "augment" non-accumulated factors in the same way as technological progress, and induce growth in real output. Further, since countries differ largely as far as raw materials intensity is concerned, declining real cost of commodities induces international capital flows and differing growth rates among countries even in steady state. In a world of constrained international capital

[11] The partial derivative of the marginal product of K-capital with respect to H-capital is everywhere above zero.

mobility, the model predicts that relatively open, resource-intensive economies with a high investment rate in H-capital will grow fastest and attract the largest inflows of foreign investment. Recall, however that resource intensity refers to the relative importance of raw materials compared to raw labor, not the use of raw materials as a share of GDP or gross output.

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