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THE WORLD INCOME DISTRIBUTION

Daron Acemoglu, MIT
Jaume Ventura, MIT

Working Paper 01-01
December 2000

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THE WORLD INCOME DISTRIBUTION*

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December 22, 2000

Abstract

We show that even in the absence of diminishing returns in production and technological spillovers, international trade leads to a stable world income distribution. This is because specialization and trade introduce de facto diminishing returns: Countries that accumulate capital faster than average experience declining export prices, depressing the rate of return to capital and discouraging further accumulation. Because of constant returns to capital accumulation from a global perspective, the time-series behavior of the world economy is similar to that of existing and technologies. Because of diminishing returns to capital accumulation at the country level, the cross-sectional behavior of the world economy is similar to that of existing exogenous growth models: Cross-country variation in economic policies, savings and technology translate into cross-country variation in incomes, and country dynamics exhibit conditional convergence as in the Solow-Ramsey model. The dispersion of the world income distribution is determined by the forces that shape the strength of the terms of trade effects--the degree of openness to international trade and the extent of specialization. Finally, we provide evidence that countries accumulating faster experience a worsening in their terms of trade. Our estimates imply that, all else equal, a 1 percentage point faster growth is associated with approximately a 0.7 percentage point decline in the terms of trade.

Keywords: cross-country income differences, endogenous growth, international trade, specialization, terms of trade effects.

JEL Classification: F43, O40, O41, F12

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1 Introduction

Figure 1 plots income per worker relative to the the world average in 1990 against its 1960 value, and draws the 45 degree line for comparison. This picture of the world income distribution raises two questions: First, why are there such large differences in income across countries? For example, some countries, such as the U.S. or Canada, are 30 times as rich as others such as Mali or Uganda. Second, why has the world income distribution been relatively stable since 1960? A number of growth miracles and disasters notwithstanding, the dispersion of income has not changed much over this period: most observations are around the 45 degree line and the standard deviation of income is similar in 1990 to what it was in 1960 (1.06 vs. .96).[1]

Existing frameworks for analyzing these questions are built on two assumptions: (1) "shared technology" or technological spillovers: all countries share advances in world technology, albeit with some delay in certain cases; (2) diminishing returns in production: rates of return to accumulable factors, such as capital, decline as these factors become more abundant. The most popular model incorporating these two assumptions is the neoclassical (Solow-Ramsey) growth model. All countries have access to a common technology, which improves exogenously. Diminishing returns to capital in production pulls all countries towards the growth rate of the world technology.[2] Differences in economic policies, saving rates and technology do not lead to differences in long-run growth rates, but in levels of capital per worker and income. The strength of diminishing returns determines how a given set of differences in these country characteristics translate into differences in capital and income per worker.[3]

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[1]Among subsets of countries with similar institutional structures there is substantial narrowing of differentials. For example, the standard deviation of log income per worker among OECD economies was 0.53 in 1960 and fell to 0.30 in 1990. In contrast, there appears to be significant widening of income differentials during the 100 years before 1960. See, for example, Durlauf (1995) and Quah (1997) on changes in the postwar post-war world income distribution, and Parente and Prescott (1994) and Jones (1997) on its relative stability. See Pritchett (1997) for the widening of the world income distribution since 1870.

[2]E.g., Barro (1991), Mankiw, Romer and Weil, (1992), Chari, Kehoe, and McGrattan (1995), Parente and Prescott (1994), and Mankiw (1995).

[3]A different but related story recognizes technology differences across countries. Despite these differences, backward countries share some of the technological improvements of advanced economies through spillovers. These spillovers ensure the stability of the world income distribution, and also determine how differences in country characteristics translate into income differences. See, for example, Grossman and Helpman (1991), Parente and Prescott (1994), Coe and Helpman (1995), Howitt (2000), Eaton and

This paper offers an alternative framework for analyzing the world income distribution. We show that even in the absence of diminishing returns in production and technological spillovers, international trade leads to a stable world income distribution. Countries that accumulate capital faster than average experience declining export prices, reducing the value of the marginal product of capital and discouraging further accumulation at home. They also increase the demand for products and the value of the marginal product of capital in the rest of the world, encouraging accumulation there. These terms of trade effects introduce *de facto* diminishing returns at the country level and ensure the stability of the world income distribution. Consequently, cross-country differences in economic policies, saving rates and technology lead to differences in relative incomes, not in long-run growth rates. How disperse the world income distribution will be for a given set of country characteristics is determined by the forces that shape the strength of the terms of trade effects; namely, the degree of openness to international trade and the extent of specialization.

Some degree of specialization in production is essential for the terms of trade effects we emphasize here: if domestic and foreign products were perfect substitutes, countries would be facing flat export demands, and capital accumulation would not affect their terms of trade. That countries specialize in different sets of products appears plausible. Moreover, this assumption has proved to be crucial in explaining some robust features of international trade, such as the substantial two-way trade in products of similar factor intensities and the success of the gravity equation in accounting for bilateral trade flows.[4]

We model the world as a collection of economies a la Rebelo (1991), with growth resulting from accumulation of capital. In the absence of international trade, countries grow at different rates determined by their economic policies, saving rates and technology. With international trade and specialization, the world as a whole still behaves as the standard Rebelo economy, but now all countries share the same long-run growth rate.

To understand why countries tend to grow at the same rate and what factors determine their relative incomes, consider the familiar steady-state condition equating the rate of return to savings to the effective rate of time preference. In our model, this condition takes the form

$$\frac{\text{rental rate}\left(\frac{\text{capital}}{\text{world capital}}, \text{technology}\right)}{\text{price of investment goods}} = \text{effective rate of time preference.}$$

Kortum, (1999), Barro and Sala-i-Martin (1999), and Acemoglu and Zilibotti (2001).

[4]See, for example, Helpman (1987) and Hummels and Levihnson (1995).

The rental rate depends negatively on the relative capital of the country because of terms of trade effects: countries that produce more face lower export prices and a lower value of the marginal product of capital. This condition also shows how different characteristics affect relative incomes. In the steady state, countries with lower rates of time preference and lower price of investment goods (those with fewer distortions affecting investment) will have lower rental rates, hence higher relative capital and income. Countries with better technologies will be richer, in turn, because they have higher rental rates for a given level of relative capital and income.

Despite rich interactions across countries, we show in Section 3 that cross-country income differences take a simple form, analogous to the basic Solow-Ramsey model. We also show that cross-country income differences and the rate of conditional convergence depend on the strength of the terms of trade effects, not on the capital share in output as in the Solow-Ramsey model. For plausible values of the elasticity of export demand and the share of exports in GDP, the terms of trade effects are strong enough to generate an elasticity of output to capital sufficient to account for observed differences in incomes and the speed of conditional convergence.

In Section 3 we also provide evidence of terms of trade effects. We look at cross-country growth regressions to isolate differences in growth rates due to accumulation. As emphasized by Barro (1991) and Barro and Sala-i-Martin (1995), countries that are poor relative to their steady state income level accumulate faster. We show that this faster accumulation is also associated with a worsening in the terms of trade. Our estimates imply that holding technology and other determinants of steady-state income constant, a 1 percentage point faster growth is associated with a 0.7 percentage point deterioration in the terms of trade. With terms of trade effects of this magnitude, our model explains a significant fraction of cross-country income differences.

Our main results are derived in Sections 2 and 3 in a model with capital as the only factor of production. An implication of this framework is that factor and product prices are lower in richer countries. We extend our basic setup in Section 4 to include labor as an additional factor of production. This extended framework implies that wages should be higher in rich countries and can also account for some stylized facts regarding relative prices across countries. For example, costs of living are higher and relative prices of investment goods are lower in rich countries as in the data (see Summers and Heston, 1991, or Figure 2 below). We also demonstrate that the main predictions of the model are independent of the capital share in national product.

Sections 2, 3, and 4 consider models with exogenous specialization. Would similar results hold if countries could choose which goods, and how many goods, to produce? We consider two reasons for specialization; increasing returns in production and costly product development. We show that in both cases the terms of trade effects continue to operate and ensure a common long-run growth rate across countries. As a byproduct of this analysis, we also obtain a simple theory of cross-country total factor productivity differences: countries with lower rates of time preference (higher saving rates) have better technologies, contributing to their higher relative income. Another implication of this analysis is that whether countries share the same technology frontier or not is not essential to our results: in the model with increasing returns in production all countries share the same technology, while in the model with costly product development countries have different technologies.

Our study is related to the endogenous growth literature[5] and to papers on cross-country technological spillovers mentioned above. Howitt (2000) is most closely related to our study. He shows that in a model of Schumpeterian endogenous growth, if innovations build on a worldwide "leading-edge technology", all countries grow at the same rate, and policy and saving rate differences affect relative incomes. Howitt's results are therefore parallel to ours, but rely on widespread technological spillovers. We emphasize instead the role of commodity trade and show that even a small amount of commodity trade is sufficient for all countries to share the same long-run growth rate.

Our study also relates to the literature on international trade and growth. A first strand of the literature emphasizes learning-by-doing, and studies how international trade changes the industrial structure of countries and affects their aggregate rate of productivity growth.[6] A second strand of the literature studies how international trade affects the incentives to innovate.[7] A third strand of the literature studies how international trade affects the process of capital accumulation in the presence of some form of factor price equalization.[8] Our paper is closer to this third line of research, since we also examine

[5] See, for example, Romer (1986, 1990), Lucas (1988), Rebelo (1991), Grossman and Helpman (1991a,b), Aghion and Howitt (1992). Although we use the formulation of Rebelo with capital accumulation as the engine of growth, our results generalize to a model in which endogenous growth results from technical change as in these other papers.

[6] E.g., Krugman (1987), Stokey (1991), Young (1991) and Brezis, Krugman and Tsiddon (1993).

[7] See, among others, Segerstrom, Anant and Dinopoulos (1990), Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991).

[8] See, for instance, Stiglitz (1970) and Ventura (1997).

the effects of international trade on the incentives to accumulate capital. We depart from earlier papers by focusing on the case without factor price equalization. With factor price equalization, the rental rate of capital is independent of domestic capital and countries can accumulate without experiencing diminishing returns. Without factor price equalization, the rental rate of capital is determined by the domestic capital stock even in the absence of technological diminishing returns.

2 A World of AK Economies

In this section, we outline a world of AK economies with trade and specialization. The main purpose of this model is to demonstrate how terms of trade effects create a force towards a common growth rate across countries. We establish that any amount of international trade ensures that cross-country differences in technology, saving and economic policies translate into differences in income levels, *not* growth rates. Countries that accumulate capital faster than average experience declining export prices, reducing the rate return to capital and discouraging further accumulation. These terms of trade effects create diminishing returns to capital at the country level and keep the world distribution stable.

2.1 Description

The world we consider contains a continuum of "small" countries with mass 1. Capital is the only factor of production. There is a continuum of intermediate products indexed by $z \in [0, M]$, and two final products that are used for consumption and investment. There is free trade in intermediate goods and no trade in final products or assets.

Countries differ in their technology, savings and economic policies. In particular, each country is defined by a triplet (μ, ρ, ϕ), where μ is an indicator of how advanced the technology of the country is, ρ is its rate of time preference, and ϕ is a measure the effect of policies and institutions on the incentives to invest. We denote the joint distribution of these characteristics by $G(\mu, \rho, \phi)$ and assume it is time invariant.

All countries admit a representative consumer with utility function:

$$\int_0^\infty \ln c(t) \cdot e^{-\rho \cdot t} \cdot dt \,, \tag{1}$$

where $c(t)$ is consumption at date t in the (μ, ρ, ϕ)-country. Throughout the paper, we simplify the notation by suppressing time and country indices when this causes no confusion.

The budget constraint facing the representative consumer is

$$p_I \cdot \dot{k} + p_C \cdot c = y \equiv r \cdot k, \tag{2}$$

where p_I and p_C are the prices of the investment and consumption goods, k is capital stock, and r is the rental rate. For simplicity we assume that capital does not depreciate. Since there is no international trade in assets, income, y, must equal to consumption, $p_C \cdot c$, plus investment, $p_I \cdot \dot{k}$.

To introduce specialization, we adopt the Armington assumption that products are differentiated by origin.[9] Let μ be the number of intermediates produced by the (μ, ρ, ϕ)-country, with $\int \mu \cdot dG = M$. A higher level of μ corresponds to the ability to produce a larger variety of intermediates, so we interpret μ as an indicator of how advanced the technology of the country is. In all countries, intermediates are produced by competitive firms using a technology that requires one unit of capital to produce one intermediate.

Each country also contains many competitive firms in the consumption and investment goods sectors with unit cost functions:

$$B_C(r, p(z)) = r^{1-\tau} \cdot \left(\int_0^M p(z)^{1-\varepsilon} \cdot dz \right)^{\frac{\tau}{1-\varepsilon}}, \tag{3}$$

$$B_I(r, p(z)) = \phi^{-1} \cdot r^{1-\tau} \cdot \left(\int_0^M p(z)^{1-\varepsilon} \cdot dz \right)^{\frac{\tau}{1-\varepsilon}}, \tag{4}$$

where $p(z)$ is the price of the intermediate with index z. These equations state that the production of consumption and investment goods require the services of domestic capital and intermediates. The parameter τ is the share of intermediates in production and it will also turn out to be the ratio of exports to income. This ratio is usually interpreted as a measure of openness. The parameter ε is the elasticity of substitution among the intermediates and also the price-elasticity of foreign demand for the country's products. The inverse of this elasticity is often interpreted as a measure of the degree of specialization. We assume that $\varepsilon > 1$. This assumption rules out immiserizing growth, that is, the country becoming poorer despite accumulating more (see Bhagwati, 1958). Note that the technologies for consumption and investment goods are identical except for

[9] See Armington (1969). We make this crude assumption to simplify the analysis and highlight the implications of specialization for growth patterns in the simplest way. In Section 5, we model how countries choose the set of intermediates that they produce and provide micro-foundations for this assumption.

the shift factor ϕ. We use this parameter to measure the effect of policies and institutions on the incentives to invest. Examples of the policies and institutions we have in mind include the degree of enforcement of property rights or the distortions created by the tax code.[10]

2.2 World Equilibrium

A competitive equilibrium of the world economy consists of a sequence of prices and quantities such that firms and consumers maximize and markets clear. Our assumptions ensure that such an equilibrium exists and is unique. We prove this by construction.

Consumer maximization of (1) subject to (2) yields the following first-order conditions:

$$\frac{r + \dot{p}_I}{p_I} - \frac{\dot{p}_C}{p_C} = \rho + \frac{\dot{c}}{c}, \tag{5}$$

$$\lim_{t \to \infty} \frac{p_I \cdot k}{p_C \cdot c} \cdot e^{-\rho \cdot t} = 0. \tag{6}$$

Equation (5) is the standard Euler equation and states that the rate of return to capital, $\frac{r + \dot{p}_I}{p_I} - \frac{\dot{p}_C}{p_C}$, must equal the rate of time preference plus a correction factor that depends on the slope of the consumption path. Equation (6) is the transversality condition. Integrating the budget constraint and using the Euler and transversality conditions, we find that the optimal rule is to consume a fixed fraction of wealth:

$$p_C \cdot c = \rho \cdot p_I \cdot k. \tag{7}$$

Equation (7) implies that countries with more patient consumers—low ρ— will have lower consumption to capital ratios.

Next consider firm maximization. The production functions (3) and (4) ensure that all intermediates are produced in equilibrium. Since firms in the intermediates sector are competitive, they set their price equal to marginal cost, the rental rate of capital. So the price of any variety of intermediate produced in the (μ, ρ, ϕ)-country is equal to:

$$p = r. \tag{8}$$

[10] Jones (1995), Chari, Kehoe and McGrattan (1998) and Parente, Rogerson and Wright (2000) have emphasized the importance of such policies in explaining cross-country differences in income levels, and a range of empirical studies have shown the importance of institutional differences in affecting investment and economic performance (e.g., Knack and Keefer, 1995, Barro, 1997, Hall and Jones, 1999, Acemoglu, Johnson and Robinson, 2000).

We use the ideal price index for intermediates as the numeraire, i.e.,

$$\int_0^M p(z)^{1-\varepsilon} \cdot dz = \int \mu \cdot p^{1-\varepsilon} \cdot dG = 1. \tag{9}$$

Since all countries export practically all of their production of intermediates and import the ideal basket of intermediates, this choice of numeraire implies that p is also the terms of trade of the country, i.e. the price of exports relative to imports.[11]

Firms in the consumption and investment sectors take prices as given and choose factor inputs to maximize profits. The logarithmic preferences in (1) ensure that the demand for consumption goods is always strong enough to induce some production in equilibrium, so price equals cost:

$$p_C = r^{1-\tau}. \tag{10}$$

On the other hand, if the country starts with a large capital stock, consumers may want to dissave and there may not be any production of investment goods. We rule this possibility out by assuming that the initial capital stock is not too large. This ensures that price equals cost for the investment good as well:

$$p_I = \phi^{-1} \cdot r^{1-\tau}. \tag{11}$$

Finally, we need to impose market clearing for capital. By Walras' law, this is equivalent to imposing trade balance.[12] Each country spends a fraction τ of its own income on foreign intermediates, while the rest of the world spends a fraction $\tau \cdot \mu \cdot p^{1-\varepsilon}$ of their income on this country's intermediates. Therefore, trade balance requires

$$y = \mu \cdot p^{1-\varepsilon} \cdot Y. \tag{12}$$

where $Y \equiv \int y \cdot dG$ is world income. Equation (12) implies that when the number of varieties, μ, is larger, a given level of income y is associated with better terms of trade,

[11] Although each country is small relative to the world, it has market power because of complete specialization in the production of intermediates. So, each country may want to act as a monopolist, imposing an optimal tariff or an export tax. Whether they do so or not does not affect our results, and we ignore this possibility. In any case, a cooperative equilibrium with free trade policies is superior to a non-cooperative equilibrium in which all countries actively use trade policy, so we may think that countries have solved this coordination problem and have committed not to use trade policy.

[12] Market clearing for capital implies that $k = k_n + \mu \cdot k_i$, where k_n is capital used in the nontraded sector, and k_i is capital used in the production of each intermediate. Given the Cobb Douglas assumption, we have $k_n = (1-\tau) \cdot y/r$. Also because demand for each intermediate is of the constant elasticity form and a fraction τ of world income Y is spent on intermediates, we have $k_i = \tau \cdot p^{1-\varepsilon} \cdot Y/p$. Using $y = r \cdot k$, the market clearing condition for capital is equivalent to (12).

p, and higher rental rate of capital, since $r = p$. Intuitively, a greater μ implies that for a given level aggregate capital stock, there will be less capital allocated to each variety of intermediate, so each will command a higher price in the world market. Conversely, for a given μ, a greater relative income y/Y translates into lower terms of trade and rental rate.

2.3 World Dynamics

The state of the world economy is fully described by a distribution of capital stocks. A law of motion for the world economy consists of a rule to determine the trajectory of this distribution from any starting position. This law of motion is given by the following pair of equations for each country:[13]

$$\frac{\dot{k}}{k} = \phi \cdot r^{\tau} - \rho, \tag{13}$$

$$r \cdot k = \mu \cdot r^{1-\varepsilon} \cdot \int r \cdot k \cdot dG. \tag{14}$$

For a given cross-section of rental rates, the set of equations in (13) determine the evolution of the distribution of capital stocks. For a given distribution of capital stocks, the set of equations in (14) determine the cross-section of rental rates.

The world economy has a unique and stable steady state in which all countries grow at the same rate.[14] To describe this steady state, define the world growth rate as $x \equiv \dot{Y}/Y$, and the relative income of a (μ, ρ, ϕ)-country as $y_R \equiv y/Y$. Then, setting the same growth rate for all countries, i.e., $\dot{k}/k = \dot{y}/y = x$, we obtain the steady-state cross-section of rental rates as

$$r^* = \left(\frac{\rho + x^*}{\phi}\right)^{1/\tau} \tag{15}$$

where "*" is used to denote the steady-state value of a variable; for example, x^* is the steady-state world growth rate. Using (8), equation (15) also gives the steady-state terms of trade of the country, p^*. It is important to note that in steady state terms of trade and rental rates are constant. This highlights that the world income distribution is stable not because of continuously changing terms of trade, but because countries that accumulate more face lower terms of trade, reducing the interest rate and the incentives for further

[13]To obtain (13), we substitute the price equations, (7), (8), and (11) into the budget constraint (2). To obtain (14), we simply rewrite equation (12) using (2) and (8).

[14]Stability follows immediately since there is a single differential equation describing the behavior of each country given by (13), and this differential equation is stable because, from equation (14), a greater k leads to a lower r.

accumulation. In the steady state, both the distribution of capital stocks and relative prices are stable.

Using equations (9), (12) and (15), we can provide a complete characterization of the world distribution of income in the steady state:

$$y_R^* = \mu \cdot \left(\frac{\phi}{\rho + x^*}\right)^{\frac{\varepsilon-1}{\tau}}, \tag{16}$$

$$\int \mu \cdot \left(\frac{\phi}{\rho + x^*}\right)^{\frac{\varepsilon-1}{\tau}} \cdot dG = 1. \tag{17}$$

Equation (16) describes the steady-state world income distribution and states that rich countries are those which are patient (low ρ), create incentives to invest (high ϕ), and have access to better technologies (high μ). Equation (17) implicitly defines the steady-state world growth rate and shows that it is higher if countries have "good" characteristics, i.e., low values for ρ and high values for ϕ and μ.

International trade and specialization play an essential role in shaping the world income distribution. To see this, use equations (8), (10), (11), and (12) to write the terms of trade and the rate of return to capital as follows:

$$\text{terms of trade} = p = \left(\frac{\mu}{y_R}\right)^{\frac{1}{\varepsilon-1}}, \tag{18}$$

$$\text{rate of return} = \frac{r + \dot{p}_I}{p_I} - \frac{\dot{p}_C}{p_C} = \phi \cdot p^{\tau}. \tag{19}$$

These are the two key relative prices in our economy. Equation (18) states that for a given measure of country technology μ, the terms of trade of the country are decreasing in its relative income. Intuitively, a greater level of income translates into greater production for each variety of intermediates in which the country specializes, and this greater supply reduces the relative prices of these intermediates. Equation (19) states that for given economic policies ϕ, the rate of return to capital is increasing in the terms of trade. This is also intuitive: a higher price for the country's exports raises the value of the marginal product of capital and hence the rate of return to capital. Equations (18) and (19) together explain why countries face diminishing returns to capital.

These equations also illustrate the sources of income differences across countries. To provide incentives for accumulation, the steady-state rate of return to capital must equal the effective rate of time preference, $\rho + x^*$. Equation (19) implies that for countries with greater patience and better economic policies, lower terms of trade are sufficient to ensure accumulation (i.e., to ensure that the rate of return is equal to $\rho + x^*$). Equation (18), on the other hand, translates lower terms of trade and better technology into a greater relative income level, y_R. So countries with low values for ρ and high values for ϕ and μ will be richer.

Equations (18) and (19) also give the intuition for the stability of the world income distribution. A country with a relative income level below its steady-state value has terms of trade above its steady state (eq. (18)). Terms of trade above steady state in turn translate into a rate of return to capital that exceeds the effective rate of time preference (eq. (19)). This induces faster accumulation than the rest of the world, increasing relative income. As this occurs, the terms of trade worsen, the rate of return declines, and the rate of capital accumulation converges towards the world growth rate.

As in most growth models, both the shape of the steady-state world income distribution and the speed of convergence towards this steady state depend on the strength of diminishing returns. While in standard models diminishing returns is postulated as a property of technology, in our model it is derived from changes in relative prices resulting from international trade and specialization. Naturally, the strength of diminishing returns depends on the volume of trade and the extent of specialization. There are stronger diminishing returns when the volume of trade and the extent of specialization are greater (high τ and low ε). When τ is low, equation (19) shows that the rate of return to capital is less sensitive to changes in the terms of trade. In the limit, as $\tau \to 0$, we converge to a closed economy, the rate of return is independent of the terms of trade, and there are no diminishing returns. In this case, as in the standard endogenous growth models, very small differences in country characteristics are sufficient to create arbitrarily large differences in incomes (and also to make the process of convergence to this steady state arbitrarily slow). Similarly, when ε is high, equation (18) shows that terms of trade are less sensitive to differences in relative incomes. In the limit as $\varepsilon \to \infty$, we are back to the endogenous growth world.

3 Empirical Implications and Evidence

World income has grown steadily during the past 200 years. And over the postwar era, as suggested by Figure 1, most countries have grown at similar rates. Our model provides a unified framework for interpreting these facts. Since there are constant returns to capital accumulation from a global perspective, the time-series behavior of the world economy is similar to that of existing endogenous growth models. In particular, the world economy grows at a rate determined by policies, savings and technology. However, since there are diminishing returns to capital accumulation at the country level, the cross-sectional behavior of the world economy is similar to that of existing exogenous growth models. Cross-country variation in economic policies, savings and technologies translate into cross-country variation in incomes, and country dynamics exhibit conditional convergence as in the Solow-Ramsey model. We now discuss how our model can be used to interpret cross-country income differences and patterns of conditional convergence, and provide some evidence of terms of trade effects.

3.1 Re-Interpreting Cross-country Income Differences

Recall that in Solow's (1956) model countries save a fraction s of their income, and have access to technologies subject to diminishing returns. For example, consider the popular Cobb-Douglas aggregate production function: $y = \left(A \cdot e^{x \cdot t}\right)^{1-\alpha} \cdot k^{\alpha}$, where A is a country-specific efficiency parameter, x is the exogenous rate of technological progress, and α is the share of capital in national product. A key assumption of this framework is that technology improves at the same rate everywhere, hence x is common across countries. As usual, define income per effective worker as $\hat{y} = y \cdot e^{-x \cdot t}$. Then, steady-state income is:

$$\hat{y}^* = A \cdot \left(\frac{s}{x}\right)^{\frac{\alpha}{1-\alpha}}. \tag{20}$$

So countries that save more (high s) and are more efficient (high A) have higher per capita incomes, though all countries share the same growth rate x. The responsiveness of income to savings depends on the capital share, α. Mankiw, Romer and Weil (1992) estimated a version of equation (20) and found that it provides a reasonable fit to cross-country differences in income for $\alpha \in [2/3, 4/5]$. Similarly, Klenow and Rodriguez (1997) and Hall and Jones (1999) show that given the range of variation in capital-output ratios and education across countries, the Solow model accounts for the observed differences in income per capita without large differences in the productivity term A if $\alpha \in [2/3, 4/5]$. This implies a qualified success for the Solow model: given the share of capital in national product of approximately 1/3 as in OECD economies, the framework accounts for cross-country income differences only if there are sizable differences in productivity or efficiency (the A term).

To relate these empirical findings to our model, note that our key equation (16) is in effect identical to (20); in our model the steady-state savings rate is $s = \dfrac{x^*}{\rho + x^*}$,[15] and substituting this into (16), we have[16]

$$y_R^* = \mu \cdot \phi^{\frac{\varepsilon-1}{\tau}} \cdot \left(\frac{s}{x^*}\right)^{\frac{\varepsilon-1}{\tau}}.$$

Our model implies the same cross-country relationship as the Solow model with two exceptions: (i) the efficiency parameter A captures the effects of both the technology term, μ,[17] and the inverse of the relative price of investment goods, ϕ; and (ii) the elasticity of relative income to savings depends not on the capital share, but on the degree of specialization, ε, and the volume of trade, τ. In particular, the equivalent of α in equation (20) is $\dfrac{\varepsilon-1}{\tau+\varepsilon-1}$ in our model, so the elasticity of output to savings is decoupled from the capital share.[18]

To discuss the empirical implications of our model further, it is useful to calculate the implied elasticity of output to savings for plausible parameter values. The two crucial parameters are τ and ε. Because of Cobb-Douglas preferences, the share of traded goods, τ, is also equal to the share of exports in GDP. Except for the U.S. and Japan, this number is around 30 percent or higher for rich economies (see World Development Report, 1997). So here we take it to be $\tau = 0.3$. Next recall that ε corresponds to the elasticity of export demand. Estimates of this elasticity in the literature are for specific industries, and vary between 2 and 10, though there are also estimates outside this range (see, for example, Feenstra, 1994, or Lai and Trefler, 1999). For our purposes, we need the elasticity for the

[15] The savings rate in our model is defined as $s = p_I \cdot \dot{k}/y$. To obtain the equation in the text, simply use equations (13) and (15).

[16] In practice, Mankiw, Romer and Weil (1992) use the investment to output ratio, i rather than the savings rate. Summers and Heston (1991) construct i with a correction for differences in relative prices of investment goods across countries, so effectively $i = s/p_I$. Using this definition, an alternative way of expressing the empirical predictions of our model is

$$y_R^* = \mu \cdot \left(\frac{i}{x^*}\right)^{\varepsilon-1}.$$

In this case, the efficiency parameter, A, is simply equal to μ, and the equivalent of α in equation (20) is $(\varepsilon-1)/\varepsilon$. The quantitative predictions of our model are affected little by this change.

[17] In our full model of Section 5, we endogeneize μ and show that it depends on the rate of time reference, ρ.

[18] In this economy, the capital share in national product is equal to 1. In the next section, when we introduce labor, the capital share will no longer be 1, but the elasticity of output to savings will remain unchanged.

whole economy, not for a specific industry. Below we use cross-country data on changes in terms of trade to estimate an elasticity of $\varepsilon = 2.3$. So here we use this as our baseline estimate. With $\varepsilon = 2.3$, our model's predictions for cross-country income differences are identical to those of the Solow model with $\alpha = 0.8$. As we consider higher values for the elasticity of export demand, ε, the implied elasticity of output to savings increases even further.

3.2 Re-Interpreting Conditional Convergence

Another salient characteristic of the postwar growth process is conditional convergence. Barro (1991) and Barro and Sala-i-Martin (1995) run regressions of the form:

$$g_t = -\beta \cdot \ln y_{t-1} + Z_t' \cdot \theta + u_t, \tag{21}$$

where g_t is the annual growth rate of income of the country between some dates $t-1$ and t, and Z_t is a set of covariates that determine steady-state income. The parameter β is interpreted as the speed of (conditional) convergence towards steady state. These regressions typically estimate a value of $\beta \approx 0.02$ corresponding to a rate of conditional convergence of about 2 percent a year. Conditional convergence is consistent with the implications of the Solow-Ramsey model, but the rate of convergence is slower than that predicted by the basic model.

It is possible to obtain explicit equations for the rate of convergence to steady state in our model. Let us define the growth rate of output as $g \equiv \dot{y}/y$, then we have:[19]

$$g = x + \frac{\varepsilon - 1}{\varepsilon} \cdot (\rho + x^*) \cdot \left[\left(\frac{y_R}{y_R^*} \right)^{-\frac{\tau}{\varepsilon - 1}} - \frac{\rho + x}{\rho + x^*} \right], \tag{22}$$

When a county is at its steady state value, i.e., $y_R = y_R^*$, it grows at the rate $(x + (\varepsilon - 1) \cdot x^*)/\varepsilon$, which is a weighted average of the steady-state world growth rate, x^*, and the current world growth rate, x. When the world is also in steady state, i.e., $x = x^*$, the country grows at the world growth rate x^*. If y_R is below its steady-state value, it grows at a rate that depends on the distance away from this steady state, the elasticity of export demand, ε, the share of traded goods, τ, and the rate of time preference, ρ.

[19] To obtain this equation, we use the trade balance condition (12) and the budget constraint (2) to get an expression for y in terms of world income, Y, and the capital stock of the country, k: $y = (\mu \cdot Y)^{1/\varepsilon} \cdot k^{(\varepsilon-1)/\varepsilon}$. We then time-differentiate this equation, and substitute from (13) for $\dot{k}/k$ and (12) for r to obtain an expression for $\dot{y}/y$, and then substitute for the steady-state relative income level, y_R^*, from (16).

The speed of convergence, $\beta = -dg/d\ln y$, in this model is therefore

$$\beta = \frac{\tau}{\varepsilon} \cdot (\rho + x^*) \cdot \left(\frac{y_R}{y_R^*}\right)^{-\frac{\tau}{\varepsilon-1}}. \tag{23}$$

As in the Solow-Ramsey model, the speed of convergence is not constant; countries away from their steady states grow faster. Near the steady state, $y_R \approx y_R^*$, we have that $\beta = \frac{\tau}{\varepsilon} \cdot (\rho + x^*)$. The baseline values of parameters suggested by Barro and Sala-i-Martin (1995) imply that the term in parentheses is about 0.1.[20] With these values, the Solow model would match the speed of convergence of approximately 2 percent a year, if $\alpha = 0.8$, i.e., once again with a value of α much larger than the capital share in the data. In contrast, with our baseline elasticity of export demand $\varepsilon = 2.3$ and the share of exports in GDP $\tau = 0.3$, our model implies $\beta = 0.013$. So the model's implications are broadly consistent with the speed of conditional convergence observed in the data. With a higher elasticity of export demand, ε, the implied rate of convergence would be even slower.

3.3 Empirical Evidence on Terms of Trade Changes

At the center of our framework is the idea that as a country accumulates more capital, its terms of trade deteriorate. Is there any evidence supporting this notion? A natural place to start may be to look at the correlation between growth and changes in terms of trade. Consider equation (12) which links the terms of trade of a country to its relative income. Taking logs and time differences, we obtain

$$\pi_t = \frac{-1}{\varepsilon - 1} \cdot (g_t - x_t) + \Delta \ln \mu_t \tag{24}$$

where π_t is defined as the rate of change in the terms of trade between date t and some prior date $t-1$, g_t is the rate of growth of the country's income, x_t is the rate of growth of world income, and $\Delta \ln \mu_t$ is the change in technology. More generally, this last term stands for all changes that affect income and terms of trade positively, including changes in technology and world's tastes towards the country's products.

[20]The standard formula includes the rate of population growth, n, and the rate of depreciation of capital, δ, which we have set to zero to simplify notation. It is easy to check that if we allow for positive population growth and depreciation, the speed of convergence would be $\beta = \frac{\tau}{\varepsilon} \cdot (\rho + n + \delta + x^*)$. Barro and Sala-i-Martin suggest a parameterization with an annual discount factor of about 0.99 (i.e., $\rho = 0.02$), a depreciation rate of 5 percent, a world growth rate of 2 percent, and a population growth rate of 1 percent per annum. This implies $\rho + n + \delta + x^* \approx 0.1$.

In theory, we can estimate an equation of the form (24) using cross-country data and look at the coefficient of g_t. A negative coefficient would imply that, as in our theory, a country that accumulates faster than others experiences a worsening in its terms of trade. Unfortunately, in practice, we do not have direct measures of the technology term, $\Delta \ln \mu_t$, so the only option is to estimate (24) without this term, or with some proxies. Since changes in technology will be directly correlated with changes in income, estimates from an equation of the form (24) will be biased and hard to interpret. This is the standard identification problem, and to make progress we need to isolate changes in growth rates that are plausibly orthogonal to the omitted technology term $\Delta \ln \mu_t$. An ideal source of variation would come from countries growing at different rates because they have started in different positions relative to their steady-state income level and are therefore accumulating at different rates to approach their steady state.

How can we isolate changes in income due to accumulation? Here we make a preliminary attempt by using a convergence equation like (21). Recall that these equations relate cross-country differences in growth rates to two sets of factors: (i) a set of covariates, Z_t, which determine the relative steady-state position of the country; and (ii) the initial level of income, which captures how far the country is from its relative steady-state position. Accordingly, differences in growth due to the second set of factors approximate changes in income due to accumulation, and give us an opportunity to investigate whether faster accumulation leads to worse terms of trade.

The estimating equation is

$$\pi_t = \delta \cdot g_t + Z_t' \cdot \omega + v_t \tag{25}$$

where, as before, π_t is the rate of change in terms of trade, and g_t is the growth rate of output. We will estimate (25) using Two-Stage Least Squares (2SLS), instrumenting g_t using equation (21). The vector Z_t includes a set of covariates that Barro and Sala-i-Martin (1995) include in the growth regressions of the form (21). We include them in the second stage equation (25), since they may also affect the terms of trade. The coefficient of interest is δ, which, in our theory, corresponds to $-1/(\varepsilon - 1)$ as in (24).

The excluded instrument in our 2SLS estimation is the initial level of income, $\ln y_{t-1}$. Intuitively, there is no obvious reason for why, once we condition on income growth and other covariates, the initial level of income should affect the change in the terms of trade. Moreover, as the large literature on conditional convergence documents, the initial level of income has a strong predictive power on subsequent growth, and this effect seems to work through accumulation: countries further away from their steady-state position accumulate more.[21] This makes $\ln y_{t-1}$ an ideal instrument for estimating (25).[22]

To implement this procedure, we use data from the Barro and Lee (1993) data set for the period 1965-1985. We estimate cross-sectional regressions of the rate of change of terms of trade between 1965 and 1985 on the growth rate of income and various sets of covariates as in equation (25). Table 1 reports the results. The top panel reports the 2SLS estimate of δ, the coefficient on output growth. The middle panel reports the first-stage relationship, in particular, the convergence parameter β. Finally, the bottom panel reports the OLS estimate of δ. Different columns correspond to different sets of covariates. In all 2SLS specifications, to save space we report only the coefficients on a few of the covariates. The footnote to the table gives the full set of other covariates included in each column. In the first-stage relationship, the coefficients are very similar to the convergence equations estimated by Barro and Sala-i-Martin (1995), and we do not report them here.

In column 1, we start with a minimal set of covariates that control for human capital differences. These are average years of schooling in the population over age 25 in 1965 and the log of life expectancy at birth in 1965. Both of these variables are typically found to be important determinants of country growth rates, so they are natural variables to include in our Z_t vector. We also include a dummy for oil producers, since over the period 1965-85, the increase in the price of oil is likely to have led to an improvement in the terms of trade of these countries. The coefficient on log GDP in 1965 reported in Panel B shows the standard result of conditional convergence at the speed of approximately 2 percent a year. The estimate of the coefficient of interest, δ, in column 1 is -0.73 with a standard error of 0.31. This estimate implies that a country growing 1 percentage point faster due to accumulation experiences a 0.73 percentage point decline in its terms of trade. This estimate is statistically significant at the 5 percent level. The coefficient on years of schooling is insignificant, while the coefficients on life expectancy and the

[21]In the presence of technological convergence, countries below their steady state may also be improving their technologies, and $\ln y_{t-1}$ may be correlated with $\Delta \ln \mu_t$. In this case, our estimate of δ would be biased upwards, stacking the cards against finding a negative δ. More generally, this consideration suggests that we may want to interpret our estimate of the strength of the terms of trade effects as a lower bound.

[22]There is a debate on how regressions of the form (21) should be interpreted, and whether the coefficient on $\ln y_{t-1}$ is biased or not, for example because of attenuation bias. See, for example, Quah (1993). This is not important for our purposes, since (21) is only the first-stage relationship for us. Attenuation bias in the first-stage relationship does not lead to bias in the 2SLS estimates.

oil producer dummy are positive and statistically significant. The coefficient on the oil producer dummy implies that, all else equal, the terms of trade of oil producers improved at approximately 0.075 percentage points a year during this period. We return to the interpretation of the other covariates later. Notice also that the OLS coefficient reported in Panel C is insignificant and practically equal to 0. The contrast between the OLS and the 2SLS estimates likely reflects the fact that the 2SLS procedure is isolating changes in income that are due to accumulation and hence orthogonal to $\Delta \ln \mu_t$.

In column 2, we enter years of primary, secondary and tertiary schooling separately, and this has little effect on the estimate of δ. In column 3, we include the average investment rate between 1965 and 1985, which again has little effect; δ is now estimated to be -0.82 with a standard error of 0.34. The next three columns add other covariates from the set of common controls of Barro and Sala-i-Martin (1995), including the ratio of government consumption expenditure to GDP, dummies for sub-Saharan Africa, East Asian countries, and Latin America, an index of political instability, a dummy for experiencing a war during this period, and the black market premium. The variables on war, political instability and black market premium are generally interpreted to capture the security of property rights faced by investors. The estimates now vary between -0.51 and -1.08, and are always significant at the 5 percent level

In column 7, we exclude the 6 oil producers from the sample (Algeria, Indonesia, Iran, Iraq, Jordan and Venezuela) and re-estimate our basic specification of column 1. This reduces the estimate of δ to -0.63 (standard error=0.35). This estimate is now marginally insignificant at the 5 percent level, but continues to be significant at the 10 percent. Column 8 instead excludes the sub-Saharan African countries, reducing the sample to 62. The estimates of δ now increases to -0.98 with a standard error of 0.4, and is significant at the 5 percent level.

In columns 1-8, the covariates are difficult to interpret because they refer to values at the beginning of the sample. For example, a 10 percent higher life expectancy in 1965 is associated with 0.5 percentage point improvement in terms of trade. This may capture the fact that initial level of life expectancy (or years of schooling) is correlated with subsequent changes in these human capital variables and therefore possibly correlated with $\Delta \ln \mu_t$ as well. In columns 9 and 10, we add changes in years of schooling and life expectancy between 1965 and 1985 to the basic regression of column 1. In column 9, these changes are entered as additional covariates. In column 10, we instead use the initial levels of years of schooling and life expectancy as excluded instruments in addition to the initial level of income. In both columns, the estimate of δ is negative and statistically significant at 5 percent. We find that changes in the years of schooling are positive and significant in the second stage, indicating that countries that increased their human capital over this period experienced improvements in their terms of trade. This is reasonable since improvements in human capital are likely to be correlated with $\Delta \ln \mu_t$.[23]

Overall, the results in Table 1 provide evidence that higher output growth due to accumulation is associated with a worsening in the terms of trade, as implied by our mechanism. Given the relatively low number of observations and the usual difficulties in interpreting cross-country regressions, this result has to be interpreted with caution. Nevertheless, it is encouraging for our theory.

We can also use the magnitudes of the coefficient estimates to compute implied values for the export demand elasticity ε. For example, the estimate in column 1, -0.73, implies $\varepsilon \approx 2.3$. This is a reasonable elasticity estimate, within the range of the industry estimates, albeit on the low side. Returning to the discussion in the previous two subsections, recall that with a value of ε around 2.3, our model comes close to explaining most of the variability in income levels across countries and the observed speed of conditional convergence. Therefore, this evidence not only points to the presence of significant terms of trade effects, but also suggests that these terms of trade effects are quantitatively important in accounting for observed patterns of income differences and growth.

4 Labor

A salient feature of the world economy is that wages for comparable workers are higher in richer countries. The model developed in the previous section is silent on this important fact, since it does not include labor as a factor of production.[24]

Another set of important regularities in the data refer to relative product prices. The

[23] We experimented with different specifications and various subsets of covariates, with similar results. We also estimated δ using decadal changes, and a random-effect model as in Barro and Sala-i-Martin (1995) and Barro (1997)'s favorite specification. In this case, the results are similar to those reported in Table 1, but more precise because of the greater number of observations. For example, the equivalent of column 1 yields an estimate of δ of -0.97 with a standard error of 0.3. The equivalent of column 3 yields an estimate of -0.95 with a standard error of 0.29, the equivalent of column 4 yields an estimate of -0.99 with a standard error of 0.32, while the equivalent of column 7 which excludes oil producers yields an estimate of -0.68 with a standard error of 0.35.

[24] With a broad view of capital k as including both physical and human capital, r would also correspond to return to human capital. Since r is lower in rich countries, this view would lead to the counterfactual implication that wages for workers with the same human capital are higher in poor countries.

cost of living (or the real exchange rate) is higher in rich countries, while the price of investment goods relative to consumption goods is lower in rich countries. Figure 2 plots the cost of living and the relative price of investment goods for the set of 1985 benchmark countries of the Summers and Heston (1991) dataset. The figure shows a clear positive relationship between income per capita and the cost of living, and a negative relationship between income and the relative price of investment goods. While the model in the previous section can account for the differences in the relative price of investment goods as a result of differences in ϕ, it is at odds with the cost of living variations, as it implies that both consumption and investment goods should be cheaper in rich countries.[25]

These observations on wages and costs of living are likely to be related. The trade literature typically explains higher costs of living with higher wages (Balassa, 1964; Samuelson, 1964; Bhagwati, 1984; Kravis and Lipsey, 1983). Intuitively, when the law of one price applies for traded goods, differences in the cost of living reflect differences in the prices of nontraded goods. Nontraded goods consist mostly of services and tend to be labor intensive. So cross-country differences in the price of nontraded goods and the cost of living simply mirror cross-country differences in wages.

In this section, we introduce labor as a production factor in our baseline model of Section 2. While this modification has no effect on the predictions regarding the world income distribution, it generates higher wages and higher costs of living in richer countries. It also demonstrates that our key results, including the responsiveness of income to savings and economic policies, do not depend on the capital share in national product.

4.1 The Model with Labor

We add two assumptions to our model from Section 2. First, the production of the consumption good now requires labor. In particular, we adopt the following unit cost function:

$$B_C\left(w, r, p\left(z\right)\right) = w^{(1-\gamma)\cdot(1-\tau)} \cdot r^{\gamma\cdot(1-\tau)} \cdot \left[\left(\int_0^M p(z)^{1-\varepsilon} \cdot dz\right)^{\frac{\tau}{1-\varepsilon}}\right], \tag{26}$$

which is identical to equation (10), except for the presence of domestic labor services in production.

[25]Equations (10), (11), and (15) imply that both consumption and investment goods should be more expensive in countries that are poorer because of low ϕ and high ρ. On the other hand, the relative price of investment goods in our model is simply ϕ^{-1}. So countries with high ϕ, which are, ceteris paribus, richer, also have lower relative prices of investment goods as in the data.

Second, each consumer supplies one unit of labor inelastically. The budget constraint of the representative consumer then becomes:

$$p_I \cdot \dot{k} + p_C \cdot c = y \equiv r \cdot k + w, \tag{27}$$

where w is the wage rate. The rest of the assumptions in Section 2.1 remain the same. The model in that section is therefore the limiting case in which $\gamma \longrightarrow 1$. In this limit, labor is not used in production and the wage is zero.

The description of the world equilibrium in Section 2.2 needs to be revised. Consumers now maximize the utility function (1) subject to the new budget constraint (27). The solution to this problem still involves the Euler equation (5) and the transversality condition (6). Once again integrating the budget constraint and using the Euler and transversality conditions, we obtain the consumption rule as:

$$p_C \cdot c = \rho \cdot \left(p_I \cdot k + \int_0^{\infty} w \cdot e^{-\int_0^t \frac{r + \dot{p}_I}{p_I} \cdot dv} \cdot dt \right). \tag{28}$$

The optimal rule is still to consume a fixed fraction of wealth, which now also includes the net present value of wages.

The existence of labor income has no effect on firms in the intermediate and investment goods sectors. So equations (8) and (11) still apply. But the condition that price equals marginal cost for the firms in the consumption good sector is now given by:

$$p_C = w^{(1-\gamma)\cdot(1-\tau)} \cdot r^{\gamma\cdot(1-\tau)}, \tag{29}$$

so prices of consumption goods depend on the wage rate.

Since we now have two factor markets, the trade balance condition, (12), is not sufficient to ensure market clearing, and we need to add a labor market clearing condition to complete the model. Labor demand comes only from the consumption goods sector, and given the Cobb-Douglas assumption, this demand is $(1-\gamma)\cdot(1-\tau)$ times consumption expenditure, $p_C \cdot c$, divided by the wage rate, w. So the market clearing condition for labor is:

$$1 = (1-\gamma)\cdot(1-\tau)\cdot\frac{p_C \cdot c}{w}. \tag{30}$$

It is useful to note that (30) implies labor income, w, is always proportional to consumption expenditure. Using this fact, we can simplify the optimal consumption rule, (28), to obtain

$$p_C \cdot c = \frac{\rho}{1-(1-\gamma)\cdot(1-\tau)} \cdot p_I \cdot k. \tag{31}$$

The law of motion of the world economy is again described by a distribution of capital stocks, but now this distribution is given by a triplet of equations for each country:[26]

$$\frac{\dot{k}}{k} = \phi \cdot r^{\tau} - \rho. \tag{32}$$

$$r \cdot k + w = \mu \cdot r^{1-\varepsilon} \cdot \int (r \cdot k + w) \cdot dG. \tag{33}$$

$$\frac{w}{r \cdot k + w} = \frac{(1-\gamma) \cdot (1-\tau) \cdot \rho}{[\gamma + (1-\gamma) \cdot \tau] \cdot \phi \cdot r^{\tau} + (1-\gamma) \cdot (1-\tau) \cdot \rho}. \tag{34}$$

Equation (32) is the law of motion for capital. It is identical to (13) and gives the evolution of the distribution of capital stocks for a given distribution of rental rates. Equation (33) is simply the new budget constraint which determines the cross-section of rental rates for a given distribution of capital stocks and wage rates. The third equation, (34), defines the labor share—wage income divided by total income. It is added to the system to determine the distribution of wages across countries. Intuitively, from (30), wage income is equal to $(1-\gamma) \cdot (1-\tau)$ times consumption expenditure, $p_C \cdot c$, which is itself proportional to capital income from (31). This equation also shows that the behavior of the labor share simply depends on the rental rate: as the rental rate increases, the labor share falls.

The steady-state world distribution of income follows from equations (32) and (33). In steady state, $\dot{k}/k = x^*$, i.e., all countries will grow at the same rate. This immediately gives the steady-state rental rate as in equation (15) from the previous section. More important for our purposes, the steady-state distribution of income and the world growth rate are still given by equations (16) and (17). Therefore, the intuition regarding the determinants of the cross-sectional distribution of income from Section 2.3 still applies. Moreover, the empirical implications, and the fit of the model to existing evidence, discussed in Section 3, are also valid.[27] But there are new implications for the cross-section of wages and some key relative prices, which we discuss below.

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[26]To obtain (32), we start with (27), and substitute for w using (30), for $p_C \cdot c$ using (31), and for p_I using (11). Equation (33) is simply the trade balance condition, (12), rearranged with $y = r \cdot k + w$. Finally, we use (11), (30) and (31) to express w as a function of k and r, and then rearrange to obtain (34).

[27]The equation describing convergence to steady state is also similar. In particular, equation (22) from the previous section still gives the rate of growth of capital income (relative to average capital income), say y_R^k, but now total income also includes labor income. We can write relative income as $y_R \equiv y_R^k / \zeta_R^k$ where ζ_R^k is the share of capital income relative to the average value of this share in the world. As long as factor shares do not change much near the steady state, equation (22) still describes the convergence properties of this more general model.

4.2 Factor Prices

Equations (32), (33), and (34) give the steady-state factor prices:

$$r^* = \left(\frac{\rho + x^*}{\phi}\right)^{1/\tau}, \text{ and} \tag{35}$$

$$w^* = \frac{(1-\gamma)\cdot(1-\tau)\cdot\rho}{[\gamma + (1-\gamma)\cdot\tau]\cdot x^* + \rho}\cdot\mu\cdot\left(\frac{\phi}{\rho + x^*}\right)^{\frac{\varepsilon-1}{\tau}}\cdot Y. \tag{36}$$

There are a number of important features to note.

In the cross section, the rental rate of capital continues to be lower in richer countries—i.e., countries with low ρ and high ϕ. In contrast, wages tend to be higher in richer countries: countries with better technology (high μ) and with better economic policies (high ϕ) will have higher wages. Both of these follow because richer countries generate a greater demand for consumption, increasing the demand for labor and wages. Interestingly, the effect of ρ on wages is ambiguous. Countries with low ρ will accumulate more and tend to be richer, and through the same mechanism, they will have a greater demand for consumption and higher wages. However, as equation (31) shows, everything else equal, a country with low ρ will consume less, which tends to reduce the demand for consumption and wages.[28]

The contrast between the behavior of the rental rate and the wage rate in the time series is also interesting. While the rental rate of capital remains constant, equation (36) shows that wages in all countries grow at the rate of world income growth. This prediction is consistent with the stylized facts on the long-run behavior of factor prices.

Finally, recall that equation (34) gives the share of labor in national product, so the capital share in national product is no longer equal to 1, while relative income differences are exactly the same as in the model of Sections 2 and 4. This highlights that, as claimed before, the result that the responsiveness of relative income to savings and economic policies depends on the share of exports in GDP and export demand elasticity was not predicated on a capital share of 1.[29]

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[28]Differentiation gives that $\frac{\partial w^*}{\partial \rho} < 0 \Longleftrightarrow \varepsilon > 1 + \frac{[\gamma+(1-\gamma)\cdot\tau]\cdot x^*\cdot\tau\cdot(\rho+x^*)}{\rho^2+[\gamma+(1-\gamma)\cdot\tau]\cdot\rho\cdot x^*}$. In other words, as long as the elasticity of foreign demand is large enough, countries with low ρ will have higher wages.

[29]More generally, although the responsiveness of output to saving rates and policies does not depend on the capital share in national product, it can be shown that it does depend on the capital share in the investment goods sector.

4.3 Costs of Living and the Relative Price of Investment Goods

We now turn to the implications of this extended model for product prices. While in the model of Section 2 both consumption and investment goods were cheaper in rich countries, now equation (29) implies that consumption goods tend to be more expensive in richer countries. This is because wages are higher in rich countries.

To discuss the implications regarding to differences in costs of living, define the cost of living in a country as the geometric average of consumption and investment goods prices, with weights $1-\sigma$ and σ:

$$e = p_C^{1-\sigma} \cdot p_I^{\sigma} = \phi^{-\sigma} \cdot w^{(1-\sigma)\cdot(1-\gamma)\cdot(1-\tau)} \cdot r^{[\sigma+(1-\sigma)\cdot\gamma]\cdot(1-\tau)}.$$

In the data, σ is usually chosen as some average share of consumption and investment goods (for example, in a benchmark country or in the world). Whether the cost of living, e, is higher in rich countries will depend on σ, and how different consumption and investment good prices are across countries. Given the share of income spent on investment is relatively small, typically around 0.2, differences in consumption good prices are likely to dominate differences in the costs of living. Therefore, we expect rich countries with higher wages to have higher costs of living.

The relative price of investment goods is now:

$$\frac{p_I}{p_C} = \phi^{-1} \cdot \left(\frac{w}{r}\right)^{-(1-\gamma)\cdot(1-\tau)}.$$

This is different from the relative price expression in the previous model because of the second term, which incorporates the fact that consumption goods are more labor-intensive than investment goods. Our model in Section 2 generated lower relative prices of investment goods in rich countries only because of differences in policies, ϕ. Now we have an additional effect reinforcing this: richer countries have higher wages, reducing the relative prices of investment goods.

5 Where Does Specialization Come From?

The previous two sections have shown how trade and specialization shape the process of world growth and cross-country income differences. At the center stage of our framework is diminishing returns due to terms of trade effects: as countries accumulate more capital, they increase the production of the commodities in which they specialize, and their terms of trade worsen. There are two assumptions underlying this mechanism:

1. Each country specializes in a different set of products.
2. The set of products a country produces is fixed (or, at least, it does not grow proportionally with its income).

The importance of these two assumptions is highlighted in equation (18). If countries were not specialized, or if $\varepsilon \to \infty$ so that different goods were perfect substitutes, they would face flat export demands. In this case, capital accumulation and greater production of intermediates would not worsen the terms of trade. If, on the other hand, the set of products in which a country specializes were proportional to its income, the production of each variety would not change with income. In this case, even with downward-sloping export demands, capital accumulation would not worsen the terms of trade. In this section, we show that these assumptions can be justified as the equilibrium of a model in which countries choose the set of goods they produce.

The two most popular explanations for why countries specialize in different products are based on increasing returns in production and costly development of new products.[30] If there are fixed costs in production, countries choose to specialize in differentiated products so as to have enough market power to recoup the fixed costs. If developing new products is costly, countries choose to develop differentiated products so as to have enough market power to recover the costs of creating new products. Not surprisingly, these elements can be used to justify the first assumption. Moreover, we show that if the fixed costs of production or the costs of creating new products require the scarce factor —labor—, the number of varieties in each country does not increase with income. This justifies the second assumption.

We next develop two models with these features. As a byproduct of this analysis, we obtain a simple theory of total factor productivity (TFP) differences, whereby countries with higher saving rates have relatively higher TFP levels. Furthermore, we show that our results do not depend on whether all countries share the same technology or not: in the model with increasing returns in production, all countries have access to the same technology frontier; in the model with costly product development, each country possesses the know-how to produce a different set of products.

[30] See Helpman and Krugman (1985) and Grossman and Helpman (1991) for a thorough discussion of models of trade under increasing returns to production and costly development of new products. Specialization may also arise because of large differences in factor proportions, even when production exhibits constant returns and there are no costs of developing new products.

5.1 Increasing Returns in Production

We now present a model in which specialization results from increasing returns in production. We introduce two modifications to the model of Section 4. First, we assume that there is an infinite mass of intermediates, and all firms in all countries know how to produce them. Hence, all countries have access to the same technology frontier. The total number of goods produced, M, as well as its distribution among countries, μ, is determined as part of the equilibrium.

Second, we assume that one worker is needed to run the production process for each intermediate. So there is a fixed cost of production equal to the wage, w. In addition, one unit of capital is required to produce one unit of each intermediate, so there is also a variable cost in terms of the rental rate of capital, r. The rest of the assumptions from Section 4 still apply.

The description of the world equilibrium needs to be revised slightly. The consumer problem is still to maximize (1) subject to the budget constraint, (27). The solution continues to be given by the Euler equation (5) and the transversality condition (6). Alternatively, the consumption rule is still represented by (28) from the previous section.

Firms in the consumption and investment goods sectors face the same problem as before, and equations (11) and (26) still determine their prices. But firms in the intermediate goods sector are now subject to economies of scale. Since an infinite number of varieties is available at no cost, no two firms will ever choose to produce the same good. So each producer is a monopolist. With isoelastic demands, all intermediate good monopolists in a country will set the same price, equal to a constant markup over marginal cost (which is equal to the rental rate, r):

$$p = \frac{\varepsilon}{\varepsilon - 1} \cdot r. \tag{37}$$

Hence, the terms of trade are no longer equal, but simply proportional, to the rental rate of capital. Because of the markup over marginal cost, each producer makes variable profits equal to ε^{-1} times its revenue, $\tau \cdot p^{1-\varepsilon} \cdot Y$. As long as these variable profits exceed the cost of entry, there will be entry. So we have a free-entry equation equating variable profits to fixed costs:

$$w = \frac{\tau}{\varepsilon} \cdot p^{1-\varepsilon} \cdot Y, \tag{38}$$

where w, the wage rate, is the fixed cost of producing an intermediate, since one worker is required to run the production process.

To complete the description of the equilibrium, we need to impose market clearing. The trade balance equation, (12), still applies. The market clearing condition for labor needs to be modified because now μ workers are employed in the intermediate sector:

$$1 - \mu = (1 - \gamma) \cdot (1 - \tau) \cdot \frac{p_C \cdot c}{w}. \tag{39}$$

The law of motion for the world was written in Section 4 as a triplet, describing the dynamics of the state variable k and factor prices, r and w. Now, this law of motion will be more complicated for two reasons. First, the consumption to capital ratio is no longer constant, so we need to add this ratio, $z \equiv \frac{p_C \cdot c}{p_I \cdot k}$, as a co-state variable, and include the transversality condition to determine the trajectory of the system. Second, the number of varieties is now endogenous and will be determined from the free-entry condition, equation (38).

The laws of motion of the key variables is given by two blocks of equations for each country:

1. *Dynamics.* For a given distribution of factor prices, r and w, and varieties, μ, this block determines the evolution of the distribution of capital stocks:[31]

$$\frac{\dot{k}}{k} = \phi \cdot r^{\tau} - \left[1 - \frac{(1-\gamma)\cdot(1-\tau)}{1-\mu}\right] \cdot z. \tag{40}$$

$$\frac{\dot{z}}{z} = \left[1 - \frac{(1-\gamma)\cdot(1-\tau)}{1-\mu}\right] \cdot z - \rho. \tag{41}$$

$$\lim_{t\to\infty} z \cdot e^{-\rho \cdot t} = 0. \tag{42}$$

   Equation (40) gives the evolution of the capital stock as a function of the rental rate, r, the number of varieties, μ, and the consumption to capital ratio, z. It differs from (32) only because the consumption to capital ratio now varies over time. Equation (41) gives the evolution of the consumption to capital ratio as a function of the number of varieties, μ. Finally, equation (42) is the transversality condition.

2. *Factor prices and varieties.* Three equations give the cross-section of factor prices and the number of varieties of intermediates as functions of the distribution of

[31]To obtain (40), we start with (27), and substitute for w using (39), for $p_C \cdot c$ using the definition $z \equiv \frac{p_C \cdot c}{p_I \cdot k}$, and for p_I using (11). Equation (41) follows from substituting for w from the market clearing equation (39) into (27) and using the definition $z \equiv \frac{p_C \cdot c}{p_I \cdot k}$.

capital stocks and consumption to capital ratios:[32]

$$r \cdot k + w = \mu \cdot \left(\frac{\varepsilon}{\varepsilon - 1}\right)^{1-\varepsilon} \cdot r^{1-\varepsilon} \cdot \int (r \cdot k + w) \cdot dG. \tag{43}$$

$$\frac{w}{r \cdot k + w} = \frac{(1-\gamma) \cdot (1-\tau) \cdot z}{(1-\mu) \cdot \phi \cdot r^{\tau} + (1-\gamma) \cdot (1-\tau) \cdot z}. \tag{44}$$

$$w = \frac{\tau}{\varepsilon} \cdot \left(\frac{\varepsilon}{\varepsilon - 1}\right)^{1-\varepsilon} \cdot r^{1-\varepsilon} \cdot \int (r \cdot k + w) \cdot dG. \tag{45}$$

Equation (12) is the trade balance equation and differs from (33) because, due to monopoly power, the rental rate and the terms of trade are not equal (see equation (37)). Equation (44) gives the labor share. It differs from (34) because the consumption to capital ratio, z, and hence the demand for labor, change over time, and also because a fraction μ of workers are now employed in the intermediate sector. Finally, (45) is the free entry condition.

The dynamics of the world economy are again stable and converge to a unique steady state. This steady state is relatively simple to characterize. It is described by two equations similar to (16) and (17):

$$y_R^* = \mu^* \cdot \left(\frac{\varepsilon - 1}{\varepsilon}\right)^{\varepsilon - 1} \cdot \left(\frac{\phi}{\rho + x^*}\right)^{\frac{\varepsilon-1}{\tau}}, \tag{46}$$

$$\int \mu^* \cdot \left(\frac{\varepsilon - 1}{\varepsilon}\right)^{\varepsilon - 1} \cdot \left(\frac{\phi}{\rho + x^*}\right)^{\frac{\varepsilon-1}{\tau}} \cdot dG = 1. \tag{47}$$

The reason why (46) and (47) differ from (16) and (17) is the presence of monopoly markup. Otherwise, they are identical to (16) and (17), and imply the same cross-sectional relationship between economic policies, saving rates and technology.

The key modification is that the number of varieties is now endogenous and given by:[33]

$$\mu^* = \tau \cdot \frac{\rho + x^* \cdot [1 - (1-\gamma) \cdot (1-\tau)]}{\rho \cdot [\tau + \varepsilon \cdot (1-\gamma) \cdot (1-\tau)] + \tau \cdot x^*}. \tag{48}$$

[32] Equation (43) follows from (12) combined with (37). The wage equation, (44), follows from the market clearing condition for labor, (39), and the definition of z in a manner analogous to the derivation of equation (34) in footnote 26. Finally the free-entry equation, (45), is obtained by substituting for world income, Y.

[33] To obtain this equation, we divide the free-entry condition (45) by the trade balance condition (43) to get $\frac{w}{r \cdot k + w} = \frac{\tau}{\varepsilon \cdot \mu}$. We then equate this to the labor share equation, (44), and then substitute the steady-state value of z from equation (41).

The only country-specific variable in this equation is ρ. So all countries have similar μ's, but those with lower discount rates (and hence higher saving rates) endogenously specialize in the production of more goods—or loosely speaking, they will "choose better technologies". Intuitively, countries with low ρ accumulate more capital and have a larger capital stock relative to their wage rates. For a given number of goods, they therefore face worse terms of trade. Consequently, they find it profitable to incur the fixed cost of production for more goods.

Now that technology differences, μ's, are endogenous, there are two determinants of cross-country income differences: countries with better economic policies (i.e., high ϕ) will be richer for the same reasons as before. Countries with lower discount rates (i.e., high ρ) will be richer both because of the reasons highlighted in Sections 2 and 4, and because they will choose to specialize in the production of more intermediates.

Notice that technology differences in this model simply translate into differences in relative incomes, not long-run growth rates. This appears plausible since there is evidence pointing to significant technology differences across countries (e.g., Klenow and Rodriguez, 1997, Hall and Jones, 1999), and as noted in the introduction, these differences do not seem to lead to permanent differences in growth rates.

To understand why the steady-state number of goods is independent of the level of capital stock or income (cfr. equation (48)), denote the fixed cost of production by f (in equation (38), we had $f = w$). Then using (12), the free-entry condition can be written as

$$\mu = \frac{\tau}{\varepsilon} \cdot \frac{y}{f}.$$

This equation states that the number of goods in which a country specializes is proportional to its income divided by the fixed cost of production. The reason why μ is constant is that as y increases f increases also. This is a consequence of the assumption that fixed costs are in terms of the scarce factor. As the country becomes richer, demand for labor (from the consumption sector) increases, causing a proportional increase in the wage rate. So, y/f and μ remain constant.

It is also useful to contemplate what would happen if the fixed cost f depended on the wage rate, but less than proportionately, say $f = w^{\zeta}$ where $\zeta < 1$. As long as $\zeta > 0$, μ would still increase with income, but less than proportionately. As a result, our key mechanism, that an increase in production translates into worse terms of trade, would continue to hold, since, from equation (18), terms of trade are proportional to μ/y, and are decreasing in y. Nevertheless, in this case, the model would not be well-behaved for another reason: as μ increases with income, the world growth rate would increase over time, eventually becoming infinite. This explains our particular choice of $f = w$ to preserve steady endogenous growth.

5.2 Costly Product Development

We next present a model in which specialization results from costly product development. We simply introduce one modification to the model of Section 4. Now firms in the intermediates sector can develop new products by undertaking R&D. Each worker employed in an R&D firm discovers new products at the flow rate λ. We also assume that existing products become obsolete at the flow rate δ.

Let l be the number of workers devoted to R&D. Then our assumptions imply that the law of motion for the number of varieties that the country produces is given by

$$\dot{\mu} = \lambda \cdot l - \delta \cdot \mu. \tag{49}$$

A firm that discovers a new product receives a perfectly enforced patent.[34] As a result, firms in different countries know how to produce different sets of intermediates. We maintain the rest of the assumptions from Section 4.

The description of the world equilibrium needs to be revised slighlty. The consumer problem is still to maximize (1) subject to the budget constraint, (27). The solution continues to be given by the Euler equation (5) and the transversality condition (6).

Firms in the consumption and investment goods sectors face the same problem as before, and equations (11) and (26) still determine their prices. Firms in the intermediates sector are monopolists as in the previous subsection. Since they face isoelastic demands, they set their prices as in (37). In addition, they undertake R&D to discover new products. Let v be the value of a new product. By standard arguments, this value must satisfy the Bellman (asset value) equation:

$$\left(\frac{r + \dot{p}_I}{p_I} - \frac{\dot{p}_C}{p_C}\right) \cdot v = \frac{\tau}{\varepsilon} \cdot p^{1-\varepsilon} \cdot Y - \delta \cdot v + \dot{v}. \tag{50}$$

Equation (50) equates the opportunity cost of holding the asset, i.e., the interest rate times the value of the product to the flow return. This flow return consists of the flow of

[34] We assume that there is no international enforcement of intellectual property rights, so firms have to use the products in the country in which they are located.

profits net of obsolescence and the appreciation in the asset value. Associated with this Bellman equation, we impose the standard no-bubble condition.

Firms allocate labor to R&D until the value of the marginal product of a worker, $\lambda \cdot v$, equals the wage, w. So

$$\lambda \cdot v = w. \tag{51}$$

Finally, we impose market clearing. The trade balance equation (12) still ensures market clearing for capital, while the market clearing condition for labor is now modified to

$$1 - l = (1-\gamma) \cdot (1-\tau) \cdot \frac{p_C \cdot c}{w}, \tag{52}$$

where recall that l is employment in the R&D sector. This equation is identical to (39) except that instead of μ workers employed to run firms, we now have l workers employed in the R&D sector.

For simplicty, we consider only the steady state of this model. In this steady state the rental rate r is still given by (15), and since world demand grows at the rate x^*, we have $\dot{v}/v = x^*$. Using the trade balance equation (12) together with (15), and (50), we can rewrite the free entry condition (51) as

$$\frac{\rho - \delta}{\lambda} \cdot w = \frac{\tau}{\varepsilon} \cdot p^{1-\varepsilon} \cdot Y. \tag{53}$$

This only differs from (38) in the previous subsection because of the term $(\rho - \delta)/\lambda$ on the left-hand side. This term incorporates the fact that labor costs are not costs for operating, but R&D costs incurred only initially.

Equation (53) implies that in steady state, income and wages have to grow at the same rate. With a similar reasoning to that in the previous subsection, this is only consistent with (52) if the amount of labor allocated to the R&D sector is constant. From (49), this implies $\dot{\mu} = 0$, that is, the steady-state number of varieties produced in each country is constant and equal to

$$l^* = \frac{\delta \cdot \mu^*}{\lambda}.$$

Given the steady-state rental rate, (15), income differences across countries are once again given by (46) in the previous subsection.

More generally, the steady-state equilibrium is similar to that in the economy with increasing returns in production. To maximize the parallel, let us normalize $\delta/\lambda = 1$. This normalization implies that in both models, the steady-state number of workers employed in the consumption sector is $1 - \mu^*$. With this assumption, we see immediately that equation (48) from the previous subsection gives technology differences across countries.

The intuition for why the number of varieties, μ, does not grow with income is the same as in the previous subsection: fixed costs of inventing new goods are in terms of the scarce factor. So an increase in income causes a proportional increase in the wage rate and fixed costs, raising the costs and profits from inventing new goods by an equal amount. As a result, equilibrium distribution of μ's remains unchanged.

This analysis also establishes that as long as fixed costs of production underpinning specialization are in terms of the scarce factor, the general conclusions reached in the previous three sections continue to hold irrespective of whether specialization is due to increasing returns in production or endogenous technology differences. This implies that whether countries share the same technology frontier or not is inessential to our results.

6 Concluding Remarks

This paper has presented a model of the world income distribution in which all countries share the same long-run growth rate because of terms of trade effects. Countries that accumulate faster supply more of the goods that they specialize in to the world and experience worse terms of trade. This reduces the return to further accumulation and creates a demand pull on other nations. We view this model as an attractive alternative to the existing approaches where common long-run growth rates result only if all countries share the same technology.

Naturally, a theory of diminishing returns due to terms of trade effects does not preclude diminishing returns in production or cross-country technological spillovers. It is relatively straightforward—though cumbersome— to write down a model with all of these factors present and complementing each other. The more important question is their relative contribution to explaining the actual world income distribution. Here, we made a preliminary attempt at estimating the extent of terms of trade effects. Our results show that when a country accumulating faster than others experiences a worsening in its terms of trade. The estimated strength of the terms of trade effects is approximately of the right order of magnitude to account for the observed cross-country differences in income levels and speed of conditional convergence. Further empirical work on the importance of terms of trade effects and how they influence cross-country income differences appears a fruitful area for future research.

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Table 1: IV Regressions of Growth Rate of Terms of Trade

	Main regression (1)	Splitting Schooling (2)	Adding Investment Rate (3)	Adding Govern. Cons. (4)	Adding Continent Dummies (5)	Adding Political Indicat. (6)	Non-Oil Sample (7)	Non-Africa Sample (8)	Adding Change in Sch. (9)	Adding Change in Sch. (10)
					Panel A: Two Stage Least Squares					
Growth Rate of GDP	-0.732 (0.308)	-0.719 (0.305)	-0.817 (0.342)	-1.080 (0.492)	-1.029 (0.558)	-0.513 (0.258)	-0.627 (0.351)	-0.976 (0.403)	-0.706 (0.299)	-0.581 (0.225)
Years of Schooling	-0.002 (0.002)		-0.003 (0.002)	-0.003 (0.002)	-0.004 (0.002)	-0.003 (0.002)	-0.001 (0.002)	-0.002 (0.003)	-0.001 (0.002)	
Years of Primary Schooling		-0.003 (0.003)								
Years of Secondary Schooling		-0.003 (0.007)								
Years of Tertiary Schooling		0.020 (0.041)								
Log of Life Expectancy	0.053 (0.028)	0.056 (0.029)	0.034 (0.027)	0.009 (0.032)	0.005 (0.034)	-0.001 (0.028)	0.047 (0.030)	0.049 (0.041)	0.027 (0.033)	
Oil Producer Dummy	0.075 (0.011)	0.074 (0.011)	0.071 (0.011)	0.063 (0.013)	0.052 (0.015)	0.065 (0.010)		0.071 (0.013)	0.068 (0.012)	0.073 (0.013)
Investment Rate			0.114 (0.067)	0.141 (0.084)	0.084 (0.074)	0.082 (0.065)				
Government Consumption				-0.143 (0.075)	-0.129 (0.077)	-0.196 (0.074)				
Change in Years of Schooling 65-85									0.009 (0.004)	0.010 (0.004)
Change in Log of Life Expect 65-85									-0.006 (0.097)	-0.055 (0.056)
					Panel B: First Stage for Average Growth Rate of GDP					
Log of GDP 1965	-0.019 (0.004)	-0.020 (0.004)	-0.018 (0.004)	-0.015 (0.004)	-0.013 (0.003)	-0.027 (0.003)	-0.016 (0.004)	-0.020 (0.004)	-0.020 (0.004)	-0.020 (0.004)
R^2	0.36	0.37	0.46	0.50	0.67	0.72	0.35	0.31	0.47	0.47
					Panel C: Ordinary Least Squares					
Growth Rate of GDP	0.006 (0.126)	0.007 (0.128)	-0.004 (0.139)	0.042 (0.167)	0.136 (0.199)	-0.004 (0.175)	0.121 (0.115)	0.069 (0.161)	0.026 (0.133)	-0.028 (0.123)
Number of Observations	79	79	79	74	74	67	73	62	79	79

"Growth Rate of Terms of Trade" is measured as the annual growth rate of export prices minus the growth rate of import prices. The four schooling variables and log of life expectancy at birth refer to 1965 values. The oil producer dummy is for 6 countries in our sample (Algeria, Indonesia, Iran, Iraq, Jordan and Venezuela). The investment rate is the ratio of real domestic investment (private plus public) to real GDP, and the government consumption is the ratio of real government consumption net of spending on defense and education to real GDP. Three continental dummies are defined for Latin American, Sub-Saharan African and East Asian countries. The political instability variables include a dummy for countries that fought at least one war over the period 1960-85, the average of the number of assassinations per million inhabitants per year and the number of revolutions per year, and the average of the logarithm of the black market premium over the period 1965-85. Changes in years of schooling and log of life expectancy are between 1965 and 1985. All covariates in the second stage are also included in the first stage. Column 5 also includes dummies for sub-Saharan Africa, East Asia and Latin America and column 6 includes the political instability variables, the war dummy, and the log of 1 plus the black market premium. These covariates are not reported to save space. All data are from the Barro-Lee Data Set.

Excluded instrument is log of output in 1965 in columns 1-9, while in column 10, excluded instruments are log of output in 1965, years of schooling in 1965, and the log of life expectancy in 1965.

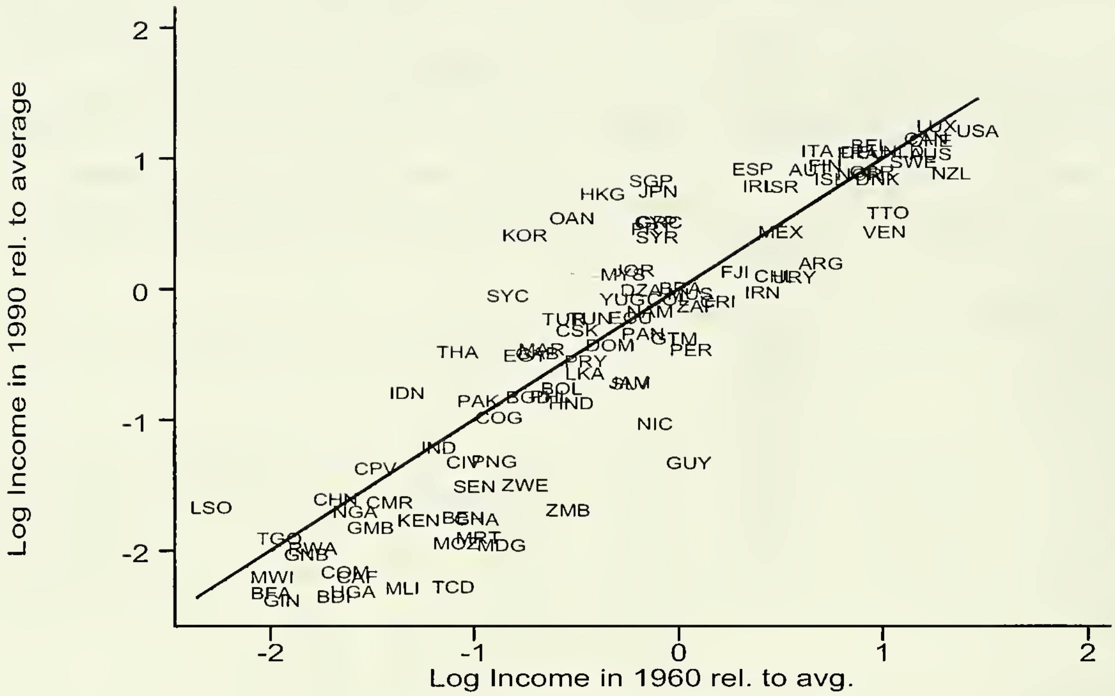

Figure 1: Log of income per worker in 1990 and 1960 relative to world average from the Summers and Heston (1991) data set. The thick line is the 45 degree line.

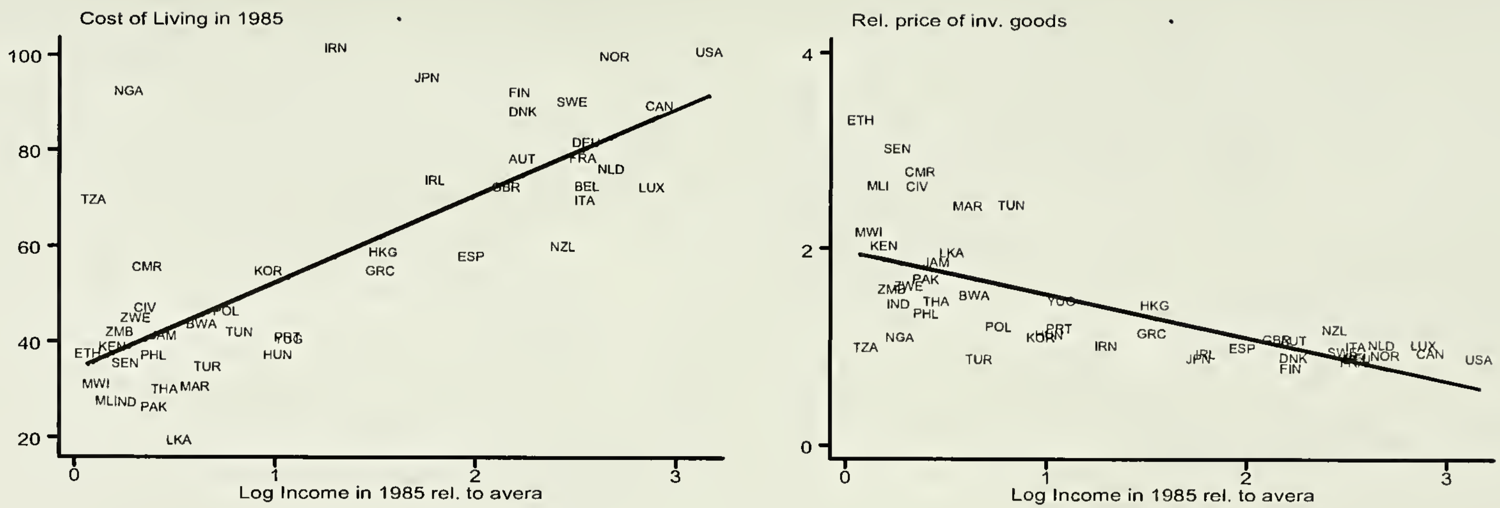

Figure 2: Differences in cost of living and the prices of investment goods relative to consumption goods. Data from Summers and Heston (1991)

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