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Abstract

Growth models of the second generation type, e.g. the Jones (1995) or Young (1998) model, all exhibit a so called weak scale effect in per capita production, i.e. larger economies should have a higher per capita production than smaller economies. However, in an open economy context the scale of the economy is less important because countries can participate in the scale of other countries through trade. This paper develops a simple open economy growth model of the second generation type which shows the relevance of the scale of the trading partners for per capita production. This model is empirically tested using time series for the G7 countries and alternatively a cross section of 80 countries for the year 2000. The scale of these economies is measured by their own scale as well as the scale of their major trading partners. The results show that there is a significant effect of the own scale and the scale of the trading partners on per capita production. Additionally the paper provides a theoretical model that shows the relevance of the weak scale effect in explaining wage inequality between different types of workers.

Keywords: Growth and Scale Effects, International Trade

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1 Introduction

Recently Jones (2004) discussed the issue of scale effects in growth models of the second generation type (e.g. Jones 1995, Kortum 1997, Segerstrom 1998, Young 1998). These models all exhibit a so called weak scale effect in per capita production, but do not share the strong scale effect of first generation growth models (e.g. Romer 1986, 1987 and 1990, Grossman and Helpman 1991 and Aghion and Howitt 1992) in the growth rate of the economy. The latter type of models predicts larger economies to grow faster than smaller, the former larger economies to possess a higher per capita production than smaller.

The reason for the weak scale effect to occur is simply due to the increasing returns specification of growth models caused by the non-rivalry of ideas which determine the state of technology. Once an idea has been discovered it can be used with no additional costs by as many production units as possible. With this setup, there exist fixed costs in setting up production, i.e. the costs of discovering the idea, and, as usual, the assumed constant marginal costs in production given the idea. This inevitably yields increasing returns to scale. Another feature of second generation models like Young (1998), Peretto (1998), Dinopoulos and Thompson (1998) and Howitt (1999) is, that the total number of ideas is tied to the scale of an economy. In the most simple case only labor is used as a traditional input factor in production and therefore the economy with the largest labor force has the highest stock of ideas which can be utilitized by the labor force.

Jones (2004) argues that the weak scale effect is more a feature than a bug of these growth models, mainly drawing on empirical studies which found evidence for the existence of such weak scale effects[1]. The studies cited in Jones (2004) include Backus, Kehoe and Kehoe (1992), Sala-i-Martin (1997), Romer and Frankel (1999), Hall and Jones (1999) and Alcala and Ciccone (2002). Backus, Kehoe and Kehoe (1992) focus on the strong scale effect but implicitly perform an analysis which is linked to the weak scale effect. They try by using ordinary regression techniques to

[1]Although the strong scale effect is not a subject of this paper, there is strong empirical evidence against it, see e.g. Jones (1995a).

explain the behavior of the growth rate of per capita GDP and per capita production in manufacturing industries for various countries. Among other explanatory variables they use the population growth rate and generally find a negative effect. This result, however, implies a negative weak scale effect because the growing scale of the economy measured by its population means a decreasing per capita production. Sala-i-Martin (1997) in his four million permutations of growth regressions does not find that the scale of an economy measured by its labor force is a robust explanatory variable. Romer and Frankel (1999) directly address the question of the presence of scale effects in the variable income per capita. Also, they are aware of the fact that international linkages measured by trade openness between countries might play an important role. Their results show a significant positive effect of the total population of an economy and the trade share, i.e. exports plus imports relative to GDP, on income per person. Hall and Jones (1999) use the population as an explanatory variable for output per worker and do not find any significant effect. Alcala and Ciccone (2002) take a similar approach as Romer and Frankel (1999) although they use an alternative measure of openness and, in addition, control for political institutions, capital intensity and human capital in the different economies. Their finding is that generally the size of the workforce has a significant positive impact on average labor productivity as does their measure of openness of an economy.

All of the aforementioned studies directly or indirectly tackle the question whether the scale of an economy explains some measure of production per capita. Some do as well take into account the effect of international linkages. However in a highly integrated world with the possibility for an economy of trade with almost every country in the world, the own labor force or population might not be the right measure for the scale of production. The argument of the theoretical part of this paper will be that the labor force of an economy is a measure of scale but also the aggregated labor force of every country with which trade takes place is part of the scale as well. Therefore, from the point of view of this paper, the studies which include a measure of trade openness in the analysis proceeded in the right direction. But not only the degree of openness to other trading partners should explain per capita production also the scale of the trading partners should enter as an explanatory variable.

It might be questioned why the presence of such a scale effect is of great economic importance. The paper argues also that in an application of growth models similar to the models of directed technical change (see Acemoglu 1998 and 2002a, Acemoglu and Zilibotti 2001 or Kiley 1999) this scale effect is an important building stone of the results. This theory is used to explain the growing wage inequality between high and low skilled workers e.g. in the US. Therefore if one wants to judge the relevance of this theory one has to decide whether the presence of scale effects is a reasonable assumption in this kind of models and whether the scale effect is present in reality.

The paper adds to the existing literature by making a theoretical and an empirical contribution. It will be shown theoretically how the scale of trading partners of an open economy determines its per capita production. The empirical part of this paper consists of a time series and a cross section analysis. In the time series context the paper tries to explain per capita production in the G7 countries and to uncover the scale effect which is caused by these countries themselves as well as by their major trading partners using data from the 1980s and 90s. In the cross section context GDP per capita for 78 countries is explained by the scale of these countries as well as their trading partners for the year 2000. The results of both the time series and the cross section analysis show a positive scale effect emerging from the scale of the particular country as well as from its trading partners. This gives further support on Jones' (2004) conclusion that the weak scale effect in second generation growth models is more a feature than a bug.

The outline of the paper is as follows. Section 2 considers theoretical foundations of the scale effect in per capita production. A version of the second generation growth model of Young (1998) is used to illustrate the scale effect for the closed and the open economy in per capita production. Section 3 considers the theory of wage inequality in a model very similar to the existing models in the theory of directed technical change. Therefore, the model of section 2 is extended to cover a two sector economy to show the effects of the scale on wage inequality. This section provides additionally a growth model with neither a strong nor a weak scale effect to show that scale effects are necessary for the argument of directed technical change to work. The empirical part of the paper is concentrated in section 4 where the data and methods used are described. Finally section 5 concludes.

2 The Model

This section develops the theoretical foundation of the paper. A version of the Young (1998) model will be used in order to study the role of the scale of an economy on its per capita production. This is will be done first for the closed economy case before turning to open economies.

2.1 The Closed Economy Case

The economy is populated by L_t workers in period t who inelastically supply one unit of labor each. The aggregate production function for the economy is

$$Y_t = L_{p,t}^{\alpha} \left(\int_0^{N_t} (\lambda_{i,t} x_{i,t})^{\theta} di \right)^{\frac{1-\alpha}{\theta}}, \tag{1}$$

where $x_{i,t}$ is the input quantity and $\lambda_{i,t}$ is the quality level of the ith variant of an intermediate input factor, α and $\theta \in (0,1)$ determine the elasticities of the production function. N_t is the available set of intermediate input factors at time t, time is discrete in this model and $L_{p,t}$ is the amount of labor used in production. Here $L_{p,t}$ is endogenous and it will become obvious later how it is related to the total exogenous labor supply L_t.

The intermediate input factors are produced by individual producers who have been engaged in the design of one particular variant. Therefore they are assumed to possess a competitive advantage in producing this variant and the production function for one of the variants for the original designer is

$$x_{i,t} = k_{i,t},$$

where $k_{i,t}$ is the input of capital goods used for production. It is assumed that capital goods can be produced from final output Y_t with a linear production technology with productivity equal to one.

The production function for a competitor who is not involved in the development of one particular variant is given by

$$x_{i,t} = \gamma^{-1} k_i,$$

where $\gamma > 1$ is a productivity parameter capturing the competitive advantage of the original developer in producing one particular variant.

Since the original developer has a competitive advantage in producing his particular variant of the intermediate input factor it is assumed that he sets a limit price γp_t, where p_t is the price of the final good produced according to equation (1) and is also the price of the capital good, in order to prevent potential competitors from entering the market for intermediate input factors.

It is clear from equation (1) that with this specification of the production function output will increase ceteris paribus in the number of intermediate input factors. However, growth can be caused in this model not only through the channel of an increasing set N_t of available variants of input factors, but as well by an increase in the quality levels $\lambda_{i,t}$ over time. Here the idea of Young (1998) is used for explaining growth in the quality level. Assume that before production of one variant of the intermediate input factors can take place a quasi-fixed cost of R&D has to be incurred in order to be able to produce with a certain level of quality. The real cost function for R&D is given by

$$F_{i,t} = \begin{cases} f e^{\mu \lambda_{i,t} / \bar{\lambda}_{t-1}} & \text{if } \lambda_{i,t} \geq \bar{\lambda}_{t-1}, \\ f e^{\mu} & \text{otherwise,} \end{cases} \tag{2}$$

with $\bar{\lambda}_{t-1} = \frac{1}{N_{t-1}} \int_0^{N_{t-1}} \lambda_{i,t-1} di$ as the average quality level in period $t-1$. Therefore developers of intermediate input factors can benefit from past quality improvements through a *standing on shoulders* argument; past improvements make future improvements cheaper. f and μ are exogenously given productivity parameters. As noted above (2) gives a real cost function in terms of a quantity of a specific production factor used to cover these fixed costs. In the following it will be assumed that simply labor is used in R&D so that $F_{i,t}$ denotes the number of workers employed in R&D by one specific input-factor producer. Hence, labor market clearing requires $L_{p,t} + L_{r,t} = L_t$, where $L_{r,t} = \int_0^{N_t} F_{i,t} di$.

Individual intermediate input factor producers choose their quality level in order to maximize profits $\pi_{i,t}$ given by

$$\pi_{it} = (\gamma - 1) p_{i,t} x_{i,t}^d - w_t F_{i,t}, \tag{3}$$

$$x_{i,t}^d = \gamma^{-\frac{1}{1-\theta}} (1-\alpha)^{\frac{1}{1-\theta}} \lambda_{i,t}^{\frac{\theta}{1-\theta}} L_{p,t}^{\frac{\alpha}{1-\theta}} \left(\int_0^{N_t} (\lambda_{j,t} x_{j,t})^\theta dj \right)^{\frac{1-\alpha-\theta}{(1-\theta)\theta}}, \tag{4}$$

where w_t is the wage rate. Here the fact is used that the marginal product of one intermediate input factor equals its price. To find the optimum one sets the first derivative of this profit function with respect to $\lambda_{i,t}$ equal to zero. The influence of $\lambda_{i,t}$ on the integral on the right hand side of the demand function is ignored since there is a continuum of input factors. Furthermore it is assumed that entry into the market for intermediate input factors occurs until profits are driven down to zero. This yields the following rule for the development of the quality level

$$\frac{\lambda_{i,t}}{\bar{\lambda}_{t-1}} = \frac{1}{\mu} \frac{\theta}{1-\theta}, \tag{5}$$

if the individual producer ignores its influence on $L_{p,t}$ through their choice of $F_{i,t}$. From (5) it is immediately clear that all producers of intermediate input factors choose the same quality level $\lambda_{i,t} = \bar{\lambda}_t$ and that $\bar{\lambda}_t$ grows at a constant rate given by exogenous parameters.

Now using the demand function (4) and integrating over all variants of intermediate input factors one finds that the production function is given by

$$Y_t = (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} N_t^{\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}} \lambda^{\frac{1-\alpha}{\alpha}} L_{p,t}.$$

What still needs to be determined is the equilibrium number of intermediate input factors N_t. Using the demand function (4) and building the integral over all variants it turns out that

$$\int_0^{N_t} \gamma p_t x_{i,t}^d di = (1-\alpha) p_t Y_t.$$

Note that this integral is also equal to $\frac{\gamma}{\gamma-1}\int_0^{N_t} w_t F_{i,t} di = \frac{\gamma}{\gamma-1} N_t w_t f e^{\frac{\theta}{1-\theta}}$ since the revenues from from selling intermediate input factors is direct proportional to the fixed costs of R&D. The real wage is given by the marginal product of labor $\alpha \frac{Y_t}{L_{p,t}}$. Considering these results, the set of intermediate input factor producers can be computed as

$$N_t = \frac{1-\alpha}{\alpha}\frac{\gamma-1}{\gamma} f^{-1} e^{-\frac{\theta}{1-\theta}} L_{p,t}. \tag{6}$$

Therefore the number of workers employed in the R&D sector of the economy is given by

$$L_{r,t} = \int_0^{N_t} f e^{\frac{\theta}{1-\theta}} = \frac{1-\alpha}{\alpha}\frac{\gamma-1}{\gamma} L_{p,t}.$$

From the labor market clearing condition it follows directly that $L_{p,t} = \frac{\alpha\gamma}{\alpha+\gamma-1} L_t$ and $L_{r,t} = \frac{(1-\alpha)(\gamma-1)}{\alpha+\gamma-1}$.

Equation (6) is precisely the source of the weak scale effect mentioned in the introduction. Since the set of available intermediate input factors is given by the extent of the labor force L_t, the per capita production in the closed economy case can be written as

$$\begin{aligned} \frac{Y_t}{L_t} &= c_1 \bar{\lambda}_t^{\frac{1-\alpha}{\alpha}} L_t^{\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}}, \qquad (7) \\ c_1 &= (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} f^{-\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}} e^{-\frac{1-\alpha}{\alpha}} \times \\ &\times \left(\frac{\alpha\gamma}{\alpha+\gamma-1}\right)^{1+\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}} \left(\frac{\gamma-1}{\gamma}\right)^{\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}} \left(\frac{1-\alpha}{\alpha}\right)^{\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}}. \end{aligned}$$

This equation shows that the per capita production grows when the quality level grows and if the total work force increases. The last effect works through an expanding set of differentiated intermediate input factors. If an economy is large it has the possibility to cover the fixed cost of R&D for many of these factors.

2.2 The Open Economy Case

This section will extend the analysis of the preceding section to the open economy case. The basic production function given by equation (1) is still valid. But now since more economies are considered, which can trade with each other, exchange of various goods is possible. The extension to the multi country case comes at the expense of losing some generality of the model. To yield a closed form solution the production function for a particular country i has now be restricted to be

$$Y_i = L_{i,p}^{\alpha} \int_0^N (\lambda_j x_j)^{1-\alpha} dj.$$

The time index has been dropped to simplify the notation. N is now the total set of intermediate input factors produced in all of the M different countries.

It is assumed that the M considered economies can engage in free trade in the capital good used for production of the intermediate input factors. This is an attempt to model capital market integration. As far as trade in intermediate input factors is concerned, it is assumed, as in Grossman, Helpman and Szeidel (2003), that there exist "iceberg" transportation costs. This means that for trade from country i to country j it is necessary for country i to produce $\tau_{ij} > 1$ units in order that one unit reaches country j. Throughout the following discussion τ_{ij} is specific for a particular pair of countries ij, $\tau_{ij} = \tau_{ji}$ and $\tau_{ii} = 1$ for all i.

Furthermore since there are now M countries, the demand for one particular variant of the intermediate input factors does not only come from the country it is designed in but also from the $M - 1$ other countries. The demanded quantity for a producer in country i for the variant l is now given by

$$x_{i,l}^d = \sum_{j=1}^{M} \left(\frac{\chi_{ij}}{p_j}\right)^{-\frac{1}{\alpha}} (1-\alpha)^{\frac{1}{\alpha}} \lambda_l^{\frac{1-\alpha}{\alpha}} L_{p,j}. \tag{8}$$

Here χ_{ij} is the price that the producer in country i charges in country j and is, following the limit price rule used in the previous section, given by $\gamma\tau_{ij}p_i$, with p_i the price for the capital good in country i. But since the capital good can be traded freely between countries $p_i = p$ for all i[2]. Finally, $L_{p,j}$ is the amount of labor employed in production in country j.

Equation (8) shows that the demand for one variant of the intermediate input factor is additive in the different countries. The optimization with respect to the quality level yields exactly the same solution as in the closed economy case considered in the preceding section. All producers will choose the same quality level $\bar{\lambda}$ and this average quality level grows with rate $\frac{1}{\mu}\frac{1-\alpha}{\alpha} - 1$.[3]

The demand for the lth variant for use in country i is given by

$$x_{i,l} = (\gamma\tau_{j,i})^{-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}} \bar{\lambda}^{\frac{1-\alpha}{\alpha}} L_{p,i}. \tag{9}$$

Integrating equation (9) over all variants and using the production function (1) one finds the reduced form production function

$$Y_i = (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} \bar{\lambda}^{\frac{1-\alpha}{\alpha}} L_{p,i} \left(\sum_{j=1}^{M} N_j \tau_{ij}^{-\frac{\theta}{1-\theta}}\right), \tag{10}$$

where N_j is the set of intermediate input factors produced in country j.

To find the number of intermediate input factors produced in country i, N_i, one first has first to integrate over the expenditure for all variants used in production in country i. It turns out that these expenditures equal $(1-\alpha)pY_i$. The zero profit condition for the market of intermediate input factors implies that the turn-over in

[2] It is assumed that within one country only variants designed in that country can be potentially reproduced by the competitive technology.

[3] It is assumed that all countries considered started off in the past with the same initial quality levels.

country i is proportional to the quasi fixed costs of R&D, i.e. the profits from selling intermediate input factors equal the quasi fixed costs of R&D

$$\int_0^{N_i} \sum_{j=1}^{M} \gamma \tau_{ij} p x_{j,m} dm = \frac{\gamma}{\gamma - 1} N_i w_i f e^{\frac{1-\alpha}{\alpha}}.$$

Together with the marginal product condition for wages, $\frac{w_i}{p} = \alpha \frac{Y_i}{L_{p,i}}$, this yields

$$N_i = \frac{1-\alpha}{\alpha} \frac{\gamma - 1}{\gamma} f^{-1} e^{-\frac{1-\alpha}{\alpha}} L_{p,i}, \tag{11}$$

and trade in intermediate input factors as well as in capital goods is automatically balanced. As in the closed economy case, the set of intermediate input factors that can be produced in one country is directly proportional to the extent of the work-force employed in production in that country. Labor is divided between production and R&D according to

$$\begin{aligned} L_{r,i} &= \frac{(1-\alpha)(\gamma-1)}{\alpha+\gamma-1} L_i, & (12)\\ L_{p,i} &= \frac{\alpha\gamma}{\alpha+\gamma-1} L_i, & (13) \end{aligned}$$

where L_i is the exogenously given work-force of country i. This result is again obtained from the fact that $L_{r,i} = \int_0^{N_i} f e^{\frac{1-\alpha}{\alpha}}$ and $L_i = L_{r,i} + L_{p,i}$.

Therefore using the reduced form production function (10) and the results (11), (12) and (13) per capita production in country i is given by

$$\begin{aligned} \frac{Y_i}{L_i} &= c_1 \bar{\lambda}^{\frac{1-\alpha}{\alpha}} \left(\sum_{j=1}^{M} \tau_{ij}^{-\frac{1-\alpha}{\alpha}} L_j \right). & (14)\\ c_1 &= (1-\alpha)^{\frac{1-\alpha}{\alpha}} \gamma^{-\frac{1-\alpha}{\alpha}} f^{-1} e^{-\frac{1-\alpha}{\alpha}} \times \\ &\quad \times \left(\frac{\alpha\gamma}{\alpha+\gamma-1} \right)^2 \frac{\gamma-1}{\gamma} \frac{1-\alpha}{\alpha}. \end{aligned}$$

Equation (14) makes clear that in an open economy both, the scale of the considered economy is important and the scale of the trading partner countries. Their scale enters weighted with a function of the transportation costs. Equation (14) is the main result of this section and serves as the motivation for the empirical analysis of section 4. Note that this a special case for the weak scale effect. Due to the assumptions about the production function for the open economy case the elasticity of production per worker with respect to the scale given by $\sum_{j=1}^{M} \tau_{ij}^{-\frac{1-\alpha}{\alpha}} L_j$ is equal to 1. In the empirical section a more general relationship will be explored. But before considering the empirics, the following section deals with an application of this growth model to emphasize the importance of the existence of the weak scale effect.

3 The Weak Scale Effect and Wage Inequality

3.1 A Model with the Weak Scale Effect

This section will deal with wage inequality between two distinct groups of workers, e.g. one can think of high and low skilled.

There is a large amount of literature on wage inequality between high and low skilled workers (for a review of the literature see Acemoglu 2002b). The argument in this section will basically build on the observation found in Acemoglu (1998) and Kiley (1999) that during the last decades two developments took place. First, the relative supply of high skilled workers increased very strong. Second, despite the rise in supply, the price of high skilled labor, i.e. the wage rate, did not decrease but even increased significantly. The remainder of the section will build a simple two-sector model, using the results of the preceding sections, which can account for this development. It will be shown that this result can be explained exactly by the weak scale effects of growth models of the second generation type.

To keep the analysis simple just consider a duplication of the economy dealt with in the closed economy section to yield an economy with two sectors[4]. This means, there are as mentioned before two distinct types of workers and L_S and L_U denote their quantities. The time index has been dropped.

The basic idea is that both sectors work on their own, i.e. they use their specific

[4]It would also be possible to consider the open economy case. This yields the same conclusions but with a more complicated analysis.

output to produce capital goods which are used in turn to form differentiated intermediate input factors, sector specific labor is used to conduct R&D, the set of available intermediate input factors and their quality levels are also sector specific. Of course in this situation two different types of final goods are produced and must be used in the economy. For simplicity assume that these two types of goods, Y_S and Y_U are combined in a final production step to yield the final consumption good Y,

$$Y = Y_S + Y_U. \tag{15}$$

Thus, sector production is aggregated by a simple linear production technology as in Kiley (1999). Although perfect substitutability between goods produced by high and low skilled is an extreme assumption, it can be justified with two arguments. First, one may rather think of two different ways of producing one good, one using high skilled and one using low skilled labor, instead of two different goods that need to be combined in order to produce the consumption good. Second, the model considered in this paper is a long run model and therefore is abstracted from short run substitution effects. In the long run it might be possible to substitute one type of labor perfectly with another type provided the necessary technology has been developed.

Since there are now two distinct types of labor there are also two wage rates. From section 2 it is clear that these wages are given by

$$\frac{w_S}{P} = \frac{\alpha + \gamma - 1}{\gamma} \frac{Y_S}{L_S},$$
$$\frac{w_U}{P} = \frac{\alpha + \gamma - 1}{\gamma} \frac{Y_U}{L_U},$$

where P denotes the price level which is, due to equation (15), identical for both goods. From the discussion in the section dealing with the closed economy case it is clear that an increase in the supply of one type of labor increases the per capita production in the respective sector. This will lead to an increase in the wage rate of that type of labor and to a decrease in the relative wage rate of the other type.

$$\frac{w_S}{w_U} = \left(\frac{\bar{\lambda}_S}{\bar{\lambda}_U}\right)^{\frac{1-\alpha}{\alpha}} \left(\frac{L_S}{L_U}\right)^{\frac{1-\theta}{\theta}\frac{1-\alpha}{\alpha}}, \tag{16}$$

where $\bar{\lambda}_S$ and $\bar{\lambda}_U$ are the average quality levels of intermediate input factors in the two sectors. This equation can explain why the relative wage of one type of labor can increase while the relative supply of that type of labor increases. It is also immediately clear from this equation that wage inequality is directly caused by the weak scale effect. This effect is in turn caused by the returns to differentiation which determine the effect of an increased number of intermediate input factors on per capita production. These returns to differentiation are given by the parameter θ. If this parameter is small, there is a large benefit from increasing the number of input factors and per capita production reacts strongly in response to an increase in the labor force in the particular sector.

Note the difference with respect to models of directed technical change in e.g. Acemoglu (1998, 2002a), Acemoglu and Zilibotti (2001) and Kiley (1999). In that kind of models the so called market size effect replaces the weak scale effect. The market size effect is a growth effect. It is present because growth models of the type found in Romer (1986, 1987 and 1990), Aghion and Howitt (1992) or Jones (1995b) are used. In the two former kinds of models the growth effect is a direct implication of the strong scale effect in these models; the larger sector grows faster. In the latter type of model things are a little bit different since the model of Jones (1995b) is also a model with a weak scale effect. However in the Jones (1995b) model the growth rate of one sector is free of scale effects only on the balanced growth path. Off the balanced growth path the model behaves like a first generation growth model, i.e. the larger sector grows faster. Therefore, throughout the adjustment to a shock in the supply of one type of labor a strong scale effect is at work leading to the market size effect. In the model presented in this section the market size effect caused by the strong scale effect is replaced through a level effect caused by the weak scale effect.

As mentioned earlier in this section the model has been designed to cover long run effects. This is also the reason why the usual substitution effect is missing here. Usually, if the relative supply of one type of labor increases, the corresponding relative wage should decline because of price effects. If the supply of one type of labor increases, output of the type of good produced by this kind of labor increases as well and its price should decline leading ceteris paribus to a decreasing wage rate. Although this effect is absent from the model due to the assumption that goods produced by high and low skilled are perfect substitutes, one can reintroduce this effect by assuming that in the short run the use of capital goods is fixed because of frictions. Then, due to the declining marginal product of labor, there is an elasticity of substitution between high and low skilled workers smaller than infinity and equal to $\frac{1}{1-\alpha}$. In the short run there would be a substitution effect leading to decline in the relative wage rate of the type of labor whose relative supply increases. In the long run, however, the use of capital goods would be allowed to adjust accordingly and the weak scale effect discussed above would lead to an increase in the relative wage as a response to an increase in relative supply.

3.2 A Model without the Weak Scale Effect

As can be seen in the discussion of the model in the previous subsection, the weak scale effect is crucial for the explanation of wage inequality as a response to changes in the relative supply of different types of labor. It is possible, however, to build a model that possesses neither a weak nor a strong scale effect to show that once the scale effects disappear, the source of wage inequality also disappears. To stress this point, this subsection considers another type of growth model, since the weak scale effect can't be removed from the above model.

Consider an economy which produces final output Z_j in sector j with the following production technology

$$Z_j = \int_0^{N_j} (\lambda_{i,j} z_{i,j})^{\delta} di,$$

where $\lambda_{i,j}$ is again the quality level and $z_{i,j}$ is the quantity used in production of an intermediate input factor. $\delta \in (0,1)$ determines its marginal productivity. It is clear that there are now decreasing returns to scale in the use of the intermediate input factors given the set of available input factors N_j.

This model is even simpler to solve than the model in section 2, dealing with the closed economy case. Therefore, only the results are presented here. It is assumed as in section 2 that the developer of an intermediate input factor has a comparative advantage in producing his particular variant and can set prices as a mark-up γ over marginal costs[5]. The intermediate input factors are produced using sector specific labor only and the growth of the quality level is modelled as in section 2. R&D is conducted by sector specific labor. Computing the demand function for one input factor and using the zero profit condition yields an equilibrium number of input factors

$$N_j = \frac{\gamma - 1}{\gamma} e^{-\frac{\delta}{1-\delta}} L_j,$$

where L_j is the labor supply to sector j. Again the number of variants of the intermediate input factors for a sector is directly proportional to its scale of the work force.

Since the intermediate input factors are produced from labor, labor market clearing demands

$$z_{i,j} = \frac{1}{\gamma} \frac{L_j}{N_j}.$$

With these results the production function for one sector j can be written as

$$Z_j = \left(\frac{\bar{\lambda}_j}{\gamma}\right)^{\delta} N_j^{1-\delta} L_j^{\delta} = \left(\frac{\gamma - 1}{\gamma}\right)^{1-\delta} \left(\frac{\bar{\lambda}_j}{\gamma}\right)^{\delta} e^{-\delta} L_j.$$

[5]The intermediate input factors are demanded until their marginal product reaches the price. However due to the decreasing returns to scale profits are earned in the final production stage. To reach an equilibrium in the consumption goods market where supply equals demand it can be assumed that the final production stage is owned by the household sector, i.e. the workers, and that profits are distributes equally among them.

This equation makes clear that there are constant returns to scale in the aggregate sector production although there are diminishing returns to scale in the intermediate input factors before the adjustment of the number of variants is taken into account. Also it is obvious that per capita production is now free of any scale effect, i.e. the weak scale effect disappeared. The model still predicts productivity growth through growth in the average quality level for intermediate input factors in sector j which grows at rate $\frac{1}{\mu}\frac{\delta}{1-\delta} - 1$ from period to period. If one assumes now an aggregation technology analogous to equation (15), $Z = \sum_{j=1}^{J} Z_j$, where Z is the consumption good produced from output of the J sectors, it follows that labor supply does not influence wage inequality in the long run. The relative wage between workers of two sectors k and l is now given by

$$\frac{w_k}{w_l} = \left(\frac{\bar{\lambda}_k}{\bar{\lambda}_l}\right)^{\delta}.$$

Here again long run means after adjustment of technology through adjustment in N_j.

The whole discussion in this section makes clear that in technology driven models the source of wage inequality is only the presence of weak or strong scale effects. If these effects are absent from a model, as in this subsection, wage inequality as a response to changes in labor supply disappears.

4 Empirical Analysis

4.1 Review of the Literature

As mentioned in the introduction there are some studies dealing empirically with the weak scale effect in per capita production. All of these studies focus on the influence of the scale of one particular country on its productivity.

Frankel and Romer (1999) analyze two cross sections, one of 150 countries and one of the 98 countries considered in Mankiw, Romer and Weil (1992), in 1985. They regress the logarithm of per capita income on the trade share, the logarithm of population and the logarithm of the country area. Due to the possible endogeneity of trade, they use as instruments for trade the geographical characteristics of the trading partners to construct predicted values for trade. The final estimation is done by OLS and the authors find a significant positive impact of the population variable on per capita income with elasticities ranging from 0.12 to 0.35.

Hall and Jones (1999) estimate the relationship between output per worker and the social infrastructure in the particular country in 1988 for 127 countries. Social infrastructure is measured by an aggregate of an index of government anti-diversion policies and an index measuring the openness to trade. The measure of social infrastructure is instrumented by geographical characteristics. As an additional variable they add the country's population to the regression and obtain an estimated elasticity of 0.05 which is statistically insignificant at any considerable level of significance.

Backus, Kehoe and Kehoe (1992) are searching for effects of trade on growth. They find them in an extended empirical model where they regress the growth rate of production per capita in manufacturing and the average growth rate of GDP per capita between 1970 and 1985 on a trade index and among other control variables the average growth rate of the population from 1970 to 1985. Experimenting with different trade indices they estimate various elasticities of per capita production with respect to the population. They are all negative, in the case of the manufacturing sector they are not significant at the 10 percent level of significance, and range from -1.6 to -1.2.

Finally Alcala and Ciccone (2002) estimate the effect of trade, the scale of production and institutional quality on per capita GDP using IV regression techniques separately for 1985 and 1990. As instruments they use, among others, geographical characteristics of the considered countries. They consider like Frankel and Romer (1999) two sets of countries, one with 150 and one with 98 countries. The estimated elasticities of per capita GDP with respect to the workforce range from 0.14 to 0.46 and are all statistically significant.

None of the studies mentioned accounted for the possible role of the scale of the trading partners in the determination of per capita production.

4.2 Data

For testing equation (14) empirically, data on per capita production, the scale of the economies considered and of their trading partners as well as on the transportation costs are needed. The countries for which the weak scale effect is measured are the G7 countries, i.e. Canada, France, Germany, Italy, Japan, UK and USA.

The data used for per capita production is per capita GDP taken from the Penn World Tables 6.1. The variable used is RGDPCH which is measured at purchasing power parity in 1996 US Dollars using a chain index. This makes the per capita GDP comparable across countries and across time (see Summers and Heston 1991).

Concerning the scale of the economies, data on the total population is used and is also obtained from the Penn World Tables 6.1. The model in section 2 predicts that the scale of an economy should be measured by its work force but there are good reasons for not using the working population as an explanatory variable. It might be possible that GDP per capita and the extent of the work-force are determined simultaneously, i.e. the scale effect working from the extent of the work-force towards GDP and an effect emanating from GDP on the working population. This last effect could be due to an incentive of GDP per capita on the labor market participation. This could lead to a simultaneity bias in the regression analysis below and, therefore, the total population is used as a measure of the scale of an economy.

Finally, data on transportation costs are needed. Since there are no data available for the considered cross section of countries for a longer time horizon, a proxy is used. It is well known that trade patterns follow geographical patterns, i.e. trade between neighboring countries is stronger than between countries that are separated by large distances (see e.g. Frankel and Romer 1999). It is therefore natural to assume that trading costs are tied to the distance between trading partners. To proxy for transportation costs in the subsection below, the great circle distances between the capital cities of the trading partners are used.

The time period considered spans the years from 1981 to 2000, the last year covered by the Penn World Tables 6.1.

4.3 Methodology and Results

This subsection deals with the estimation of a generalization of equation (14) with a flexible elasticity . In this equation the scale of the trading partners and the transportation costs τ_{ij} between country i and country j enter. As explained in the previous subsection the scale is measured by the total population of the particular countries. Since there are no data available directly on transportation costs, a proxy for the term $\tau_{ij}^{-\frac{1-\alpha}{\alpha}}$ must be used. Here this approximation is ad_{ij}^{-1} where d_{ij} is the great circle distance between the capital cities of the countries i and j and a a scaling parameter. The inverse distance between countries is also often used as a weighting factor in spatial econometrics (see e.g. Anselin 1988).

The focus of the time series analysis lies on the weak scale effect for the G7 countries. Since these countries are highly developed they trade to some extent with almost every country in the world. Now the theoretical result in equation (14) rests on the effect of importing intermediate input factors from other countries. These input factors can be seen to represent the state of technology available in the world market. Therefore, first, the important aspect of trade is imports from other countries. Second, the countries included in the empirical version of equation (14) should represent resources of state of the art technology imports. For this reason only the top 70% of importing countries to the G7 countries, i.e. the largest importers up to the point where 70% of imports are reached, are included in the analysis. Inspecting the data in the International Trade Statistics Yearbook UN (1985-2000) leads to the conclusion that the top 70% importing countries are the major trading partners. Beyond the 70% threshold imports are widely spread in small partitions among often less developed countries.

Furthermore, from 1991 on there are a lot of countries from Eastern Europe as well as Russia and China entering the world markets. Since these countries are not considered to be exporters of state of the art technologies for most of the time horizon covered, they are excluded from the list of countries determining the scale of per capita production. To yield continuous time series the threshold was applied in the year 2000 and the scale of the importers included in 2000 was traced back to the year 1981. Table 1 (in the Appendix) summarizes the major import sources for each of the G7 countries using the 70% rule.

The scale variable generated to account for per capita production in the G7 countries is thus

$$s_i = \sum_{j=1}^{M} d_{ij}^{-1} L_j, \tag{17}$$

where L_j is measured by the total population of country j[6]. Also important according to equation (14) is the scale of the own economy. In the theoretical analysis the parameter τ_{ii}, i.e. the transportation costs within country i, was set equal to one. In the empirical analysis of this subsection, however, a measure for d_{ii} of half of the square root of the land area of country i is used to capture the negative effect of large transportation ways within a country.

For the cross section analysis, the same methodology has been applied to compute the scale variable in 2000. The cross section members are the 98 countries considered in Mankiw, Romer and Weil (1992). Due to lack of trade data and in some cases of GDP per capita only 78 countries were included in the final estimation[7].

4.3.1 Time Series Analysis

At first sight it seems tempting to interpret equation (14) in log terms as a cointegration relationship and to use methods for non-stationary time series to estimate it when working with the time series. A look at the stationarity characteristics of the time series for GDP per capita and the scale variable defined in (17) reveals that all series show a tendency of trending upward over time. For GDP per capita the panel unit root test of Levin and Lin (1993) (LL) and a Fisher type test proposed by Maddala and Wu (1999) and Choi (2001) (Fisher) was applied. The LL test has

[6]Since the scaling parameter a introduced above is assumed to be identical for all countries it has no influence on the results below and can be ignored here.

[7]The countries not considered, compared to Mankiw, Romer and Weil (1992) are: Angola, Botswana, Central African Republic, Chad, Democratic Republic of Congo, Republic of Congo, Haiti, Jordan, Liberia, Myanmar, Mauritania, Mauritius, Papua New Guinea, Sierra Leone, Sri Lanka, Sudan, Somalia, Tanzania and Uganda.

the Null of a common unit root in the seven time series which is tested against the alternative of trend stationarity. The Fisher test has the Null of individual unit roots in the time series, the alternative is trend stationarity. For GDP per capita the test statistics are -0.48 and 12.17 for LL and Fisher with corresponding marginal levels of significance of 0.32 and 0.59. Clearly the Null can not be rejected. For the scale variable things are a little bit more difficult. The reason for this is a break in the series due to the reunification of Germany in 1991. From that point of time the scale variable for all countries importing from Germany shifted upward. The only exception is Canada because Germany does not belong to its major import sources. Therefore the unit root test of Perron (1989) is applied to each of the seven series. The alternative hypothesis that was tested is that the underlying processes are individually trend stationary with a one time shift in the level of the trend. The test statistic is the usual t-statistic as in the Dickey-Fuller test. The values obtained for this statistic range from -1.45 to -3.17 for the different countries and are statistically not significant. Thus it seems also reasonable not to reject the Null of a unit root. However, the critical values tabulated in Perron (1989) are only asymptotically valid and the time series considered here are relatively short. Additionally the test might have low power in general as mentioned by Perron (1989). Looking at the graphs in figure 1, where the log of the scale variable is plotted against the time axis, might lead one to rather conclude that the scale variables might also be described as trend stationary processes. With this caveat in mind it would be dangerous to model the technological level, i.e. the quality level in equation (14), by a time trend, because it might very well be a random walk with drift. The assumption of a stochastic trend in the level of technology is also a quite often used assumption in literature (see e.g. Cogley and Nason 1995). Also in the theoretical part of this paper the result for the development of the level of quality (equation 5) is more in the spirit of a random walk with drift. Finally the inclusion of a linear time trend in a cointegration relation to proxy for the level of technology might lead to erroneous results if technology has a unit root. But since no time series for the level of technology are available, estimation of equation (14) in levels is problematic.

The strategy pursued here is to estimate a generalization of equation (14) in first log differences with individual fixed growth effects

$$\hat{\mathbf{y}}_\mathbf{t} = \boldsymbol{\nu} + \zeta \hat{\mathbf{s}}_\mathbf{t} + \boldsymbol{\xi} \mathbf{d}_\mathbf{t} + \boldsymbol{\epsilon_t}, \tag{18}$$

where $\hat{\mathbf{y}}_\mathbf{t}$ is a vector containing the annual growth rates of GDP per capita and $\hat{\mathbf{s}}_\mathbf{t}$ is a vector containing the growth rates of the scale variable defined by equation (17) for the seven countries considered. $\boldsymbol{\nu}$ is a parameter vector containing the individual growth effects to be estimated. ζ is the elasticity of GDP per capita with respect to the scale variable. To allow for period specific common growth effects, period dummies were included in the estimation. These effects are captured by the coefficient vector $\boldsymbol{\xi}$.

If the empirical counterpart of equation (14) is viewed as a linear cointegration relationship in logs and the level of technology follows an ARIMA process as e.g. in Cogley and Nason (1995), the error terms in the model (18) can be in general governed by an ARMA process. Estimating the model by OLS will nevertheless lead to consistent results, but care must be taken in making inferences from the estimates. To obtain consistent estimates of the standard errors of the coefficients of the model, the covariance matrix of the coefficients has been calculated by (see Wooldridge 2002)

$$\hat{\Sigma} = \left(\sum_{i=1}^{7} \mathbf{X}_i' \mathbf{X}_i \right)^{-1} \left(\sum_{i=1}^{7} \mathbf{X}_i' \hat{\boldsymbol{\epsilon}}_i \hat{\boldsymbol{\epsilon}}_i' \mathbf{X}_i \right) \left(\sum_{i=1}^{7} \mathbf{X}_i' \mathbf{X}_i \right)^{-1},$$

where i is the country index and $\mathbf{X}_i$ is the regressor matrix containing the observations over time. Analogously $\hat{\boldsymbol{\epsilon}}_{\boldsymbol{i}}$ contains the estimated residuals for country i over time. This estimator is valid asymptotically and can account for arbitrarily serial correlation and time varying variances in the residuals.

The estimated elasticity of per capita production with respect to the scale variable $\hat{\zeta}$ is 0.65 with an estimated standard error of 0.21. Thus a result which is different from the extrem result of the theoratical model with a unit elasticity. The overall R^2 for the regression is 0.50.

A more dynamic approach is to specify the relationship between the growth rate of GDP per capita and the scale variable as a distributed lag model

$$\mathbf{\hat{y}_t} = \boldsymbol{\nu} + \sum_{k=1}^{p} \eta_k \mathbf{\hat{y}_{t-k}} + \sum_{l=0}^{q} \zeta_l \mathbf{\hat{s}_{t-l}} + \boldsymbol{\xi} \mathbf{d_t} + \boldsymbol{\epsilon_t}, \tag{19}$$

The model in (19) has been estimated by OLS and GMM (Arellano and Bond 1991) since the OLS estimator might be biased because of the presence of lagged dependent variables[8]. If the model in (14) is interpreted as a cointegration relationship then the usual GMM estimator of Arellano and Bond (1991) might be problematic since it uses in this case lags of $\mathbf{\hat{y}_t}$ of order $p+1$ as instruments. If the process governing the technological level is for example an ARIMA(2,1,0) process then the error term in (19) is correlated with lags of $\mathbf{\hat{y}_t}$ of order $p+1$ and $p+2$ and therefore only lags of order $p+3$ and higher are valid instruments.

The results of the estimators are shown in table 2 and do not seem to differ substantially. A lag structure of $p = 2$ and $q = 1$ has been used since additional lags did not show up to be significant. Column 1 shows the OLS results, in column 2 are the results of the GMM estimation and column 3 contains the results of the modified GMM estimation with lagged values of $\mathbf{\hat{y}_t}$ of order 5 and higher as instruments.

From the estimates of the model (19) it is clear that the growth rate of GDP per capita follows an autoregressive process of order two which is well behaved. The influence of the scale variable is captured by the estimates $\hat{\zeta}_0$ and $\hat{\zeta}_1$. $\hat{\zeta}_0$ is in all cases significantly positive and the estimated short run elasticities are 0.59 for OLS, 0.58 for the usual Arellano and Bond (1991) estimator and 0.57 for the modified GMM estimator.

From the results in table 2 it is now also possible to calculate the long run elasticity of per capita production with respect to the scale variable. The estimates can be obtained from $\frac{\hat{\zeta}_0+\hat{\zeta}_1}{1-\hat{\eta}_1-\hat{\eta}_2}$ and are 0.65 for OLS, 0.63 for the Arellano and Bond (1991) estimator and 0.61 for the modified GMM estimator. Thus the long run elasticity is almost equal to the estimate of the static model (18).

[8]However, the bias might be small because it vanishes with the time series dimension, see Nickell (1981).

4.3.2 Cross Section Analysis

As mentioned above the cross section considers 78 countries for the year 2000. For each of the countries the scale variable has been calculated according to equation (17). This time the model was not estimated in growth rates, but in levels. The basic empirical model was to regress the log of GDP per capita on the scale variable. However, the residuals from such a regression might be spatially correlated. For this reason, and to account for regional differences in productivity, regional dummies were included in the regression analysis for Africa, Asia, Australasia, the Indian Subcontinent, North America and South America. Additionally, as in Hall and Jones (1999), the distance from equator was added as an explanatory variable to the regression. For some countries India is an important trading partner. But since India has a extremely large population inflating the scale variable defined in (17) also a dummy variable indicating india as a trading partner was considered as an explanatory variable in the estimation.

The OLS estimation results are reported in table 3. The elasticity of GDP per capita with respect to the scale variable is 0.34 in the initial specification and 0.41 after removing the regional dummies for Asia and South America which are jointly insignificant. The coefficients for the regional dummies all show the expected signs Compared with the time series results the magnitude of the elasticity is a little bit lower. The reason for this might be that among the 78 countries in the cross section there are a lot of low developed economies with high populations and often also low developed trading partners. The impact from an increase in the scale variable due to an increase in the population with a low level of education might not be as strong as an increase in the scale of developed countries as in the G7 case.

Comparing the results with the estimates obtained in the studies cited above, they are located at the upper end of the results. However, they are not directly comparable since other studies only use as a scale variable the population or workforce of the particular economy.

The result shows a significant influence of the scale variable of an economy on its per capita production giving further support on Jones' (2004) conclusion that weak scale effects are more a feature than a bug of second generation growth models.

5 Conclusion

The weak scale effect is one of the effects observed in growth models of the second generation type. This paper has shown, using a version of the Young (1998) model, how these scale effects come into existence. The larger the economy considered, the more quasi fixed costs of R&D can be covered and the more technologically advanced is an economy. In an open economy things are a little bit different. The scale of an open economy is not constrained to its own resources, e.g. the population or the workforce, but is determined by the scale of its trading partners as well as by its own. If trading costs are low, the scale of an economy is almost given by the own scale extended by the scale of the trading partners.

These scale effects play an important role in the economics of wage inequality. An argument similar to the theory of directed technical change shows that the weak scale effect can affect the wage inequality between two types of labor, e.g. high and low skilled, in response to a change in the relative supply of labor. The effect operates through an increasing per capita production for one type of labor. Clearly this is a long run effect, emanating only after technology has adjusted to the new relative supply of labor, but has important implications for dealing with inequality. Empirically the question was addressed, whether such scale effects are indeed present in the real world or whether they are just an artifact of special kinds of theoretical growth models. The results for the G7 countries indicate that there are scale effects present in the long run and that they are significant. The analysis considered the whole economy, i.e. the scale effect was measured as the impact of the total population of the economy and its import resources on total per capita production. Future research might explain per capita production and explicitly wage inequality on a more disaggregate level, i.e. sector level with the same set of instruments. Data on the workforce on the sector level for production and non production workers are available for 37 subsectors of the manufacturing sector for various countries in the United Nations Industrial Statistics Yearbook (see e.g. UN 1991). One might use production and non-production workers as proxies for low and high skilled workers as in Berman, Bound and Machin (1997). The remaining problem with this approach would be that the endogeneity of the employed workforce for production and non production workers possibly biases the estimation results. To resolve this problem suitable instruments for the employment in the different sectors have to be found.

Nevertheless, the results obtained in this paper give support to the presence of the weak scale effect, and the corresponding assumptions in the second generation growth models seem reasonable. From this point of view trade is, on the one hand, good for a country because due to the possible specialization of production it can help to foster per capita production. One limitation of this effect must be noted. In the cases considered in this paper the scale of open economies was measured mainly by the scale of developed or highly developed trading partners. It is therefore dangerous to extrapolate this effect on the development of increasing trade with less developed countries since these countries are not likely to be able to account for a degree of specialization as developed countries with a high level of technology.

On the other hand, the weak scale effect can give rise to increasing wage inequality, an outcome which might be, from a political perspective, not desirable. This last point is especially important if there are large changes in the skill composition of the work-force like the tremendous increase in the supply of high skilled in the last decades in most developed countries.

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Appendix

Table 1: Top 70% import sources of the G7

Canada	France	Germany	Italy	Japan	UK	USA
Japan	Belgium	Austria	Austria	Australia	Belgium	Canada
USA	Germany	Belgium	Belgium	Canada	France	France
	Italy	France	France	Germany	Germany	Germany
	Japan	Italy	Germany	Indonesia	Ireland	Italy
	Netherlands	Japan	Japan	Malaysia	Italy	Japan
	Spain	Netherlands	Netherlands	Philippines	Japan	Mexico
	Switzerland	Spain	Spain	Saudi Arabia	Netherlands	South Korea
	UK	Sweden	Switzerland	South Korea	Norway	Spain
	USA	Switzerland	UK	Thailand	Spain	UK
		UK	USA	UK	Sweden	
		USA		UAE	Switzerland	
				USA	USA	

The largest importers to the G7 countries covering up to 70% of imports in 2000. Source: UN (1985-2000).

Table 2: Estimation Results Time Series

	OLS	GMM(1)	GMM(2)
$\hat{\eta}_1$	0.544	0.581	0.656
	(0.149)	(0.088)	(0.086)
$\hat{\eta}_2$	-0.295	-0.306	-0.333
	(0.091)	(0.031)	(0.037)
$\hat{\zeta}_0$	0.589	0.583	0.575
	(0.065)	(0.141)	(0.135)
$\hat{\zeta}_1$	-0.104	-0.128	-0.162
	(0.103)	(0.051)	(0.074)
Observations	119	112	112
R^2	0.668	0.291	0.228

Estimation for all models with individual growth effects and common period effects. Robust standard errors in parentheses. GMM(1) corresponds to the Arellano and Bond (1991) one-step estimator, GMM(2) denotes estimation analogous to Arellano and Bond (1991) but only with lags of order 5 or higher of the dependent variable as instruments.

Table 3: Estimation Results Cross Section

Dependent variable:	Log of GDP per capita	
Log Scale	0.338	0.411
	(0.101)	(0.107)
Africa	-1.14	-1.18
	(0.211)	(0.139)
Asia	0.358	-
	(0.249)	
Australasia	1.118	1.184
	(0.238)	(0.197)
Indian Subcont.	-1.702	-1.808
	(0.138)	(0.139)
North America	0.793	0.765
	(0.254)	(0.242)
South America	-0.028	-
	(0.190)	
Trade w. India	-0.647	-0.702
	(0.178)	(0.184)
Dist. Equ.	3.193	3.005
	(0.391)	(0.298)
Const.	6.144	5.823
	(0.678)	(0.615)
Observations	78	78
R^2	0.901	0.895

Cross section estimation by OLS. Heteroskedasticity consistent standard errors in parentheses. Distance from equator is measured by abs($latitude/90$).

Figure 1: Log of the Scale Variable