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How long is Simon's long run? : a first approach

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Abstract

Julian Simon has stated, in many of his recent publications, that population growth, although reducing income per capita in the short run through capital dilution, increases the rate of growth of that same income per capita in the long run (steady state) through technical progress brought about by the increased rates of invention and innovation caused by a bigger population. This paper intends to measure empirically the length of time needed to achieve that steady state, through the experience of three industrialised countries, by means of a time-series analysis based on the models presented by Simon in his most recent work (1986).

Much has been said since the days of Malthus about population growth and its influence over economic growth and development. Most of it, however, has remained at a very basic level of discussion or, at the most, at the level of simple comparisons of statistical data. Malthus himself based his work on a rather intuitive approach, very much influenced by his own personal beliefs and moral principles. No one could have expected much more from him, given the scarcity and poor quality of the statistical data at his time.

Without improving very much on the quality of the analysis, the debate gained momentum in the 1970s, first with the catastrophic predictions of the Club of Rome (1972) –which were based on erroneous estimates of the world's reserves of natural resources- and later with *Global 2000* (1979), the report on population issues and other related matters delivered to the President of the United States, which renewed the pessimistic outlook first depicted by the Club of Rome. It has since become usual that individual countries adopt their own population policies, as part of an integral development policy. The best known cases are those of India and China.

The counterattack to the pessimistic approach on population growth has been led by Julian L Simon, who has been arguing for more than a decade that population growth has not been systematically treated as an economic variable, thereby ignoring some of its effects on the economic environment. He is aware of the fact that population growth, *per se*, causes a reduction in income per capita in the short run, both due to the distribution of the same production among more consumers (consumption effect) and to the dilution of capital among more workers (production effect). But –his argument goes on-, this is only a static and partial effect. As years go by, the increased population is capable of increasing the stock of useful knowledge and technology at a much faster pace than that of population itself. This process leads to an increased productivity per worker and, therefore, to a higher income per capita.

Where is the trick? In his most recent publication, *Theory of Population and Economic Growth"* (1986), Professor Simon builds up a model of economic growth in which he endogenises technological progress, by relating it to population growth. Most of the growth models developed up to now, since the early developments of Harrod and Domar, include technical progress –either embodied or disembodied- as an exogenous independent variable, to account for the economic growth that cannot be explained by capital or labour alone. In this sense, "technical progress" has been the name given to a variable which economists have not been able to explain, but which adequately accounts for the *leftovers* of economic growth ("the measure of our ignorance", in the words of a well-known author). Professor Simon gives a detailed description of how technical progress is achieved and how population size and growth influence it.

This paper does not intend to prove or disprove Professor Simon's theory. Much more and better statistical data are needed for such a task. So the theory implied by Simon's model –described later in the paper- is taken here for granted. My modest intention is to try to give some hints as to how long the period needed to achieve Simon's steady state might be. There has been some discussion going on about it, still at a very preliminary stage. Here, statistical data on three industrialised countries –France, Japan and the United Kingdom- are used in trying to unveil the answer to such a crucial question.

1) The intuition and the facts behind Simon's theory

The claim by Malthus that population increases in a geometric progression, while resources and food supplies do so only in an arithmetical progression has long since been disproved. It might be true that populations of certain regions or countries have grown in a geometric progression during a certain period of time. But that rate of growth is subject to cycles, due to several causes. One of them is the change in general welfare, which is explained by the *demographic transition* theory. It is also subject to all kinds of checks throughout history (epidemic diseases, wars, natural disasters, etc). Take the case of Egypt. Its population has grown at very high rates at least during two periods over the last two thousand years (250-500ad and 1800-1950ad). And yet, the number of Egyptians was barely the same in 1950 as it was in the year 500bc.

On the other hand, that food supplies or any kind of resource needed for production trail behind population growth could not be sustained seriously by anyone, given the evidence that suggests otherwise. The world's food production per capita increased 28% in the period of 1950-1977, one of the periods of highest population growth on record. Only Africa has failed to meet the growing food demands of its population in recent years, due to a host of natural disasters and civil war problems coupled with inadequate government policies.

The alleged scarcity of natural resources is denied by the secular downward trend of commodity prices. Take anyone of them –even oil- over the period of the last 100 or 150 years; their real prices have all come down, sometimes in proportions of 30 to 1. This can be roughly explained by the fact that higher prices induce the discovery of new reserves and/or the substitution of resources in consumption or production. In this last case, the adoption of a new technology ensures an increased production or lower prices or both.

Given these facts, how can someone ever think that population growth is detrimental to economic growth and development? Very simple: by everyday experience. People live in a certain period in time (now and perhaps ten years back in the past and ten years into the future), within certain boundaries (town, region or country) and surrounded by their own personal circumstances and fellow citizens. If the population in a certain area at a certain moment in time starts to increase very quickly, any member of that community will see his own circumstances change in a way that tends to limit him somehow (the discomfort of more crowded buses or underground trains, greater pollution, higher prices due to greater demand, etc). He will experience the immediate consequences of population growth, which impose a limitation on him. He will not be able to see its long-run benefits - the ones we have discussed earlier, on the production side, and more and better facilities available to the community, brought about by a higher demand concentrated in the same area.

But, what sort of logic lies behind the fact that an increase in population may imply enhanced welfare for all in the long run, even though it obviously constrains resources in the short run? The idea is fairly simple. Think about productive resources; land, capital and labour. Is land of any use if there is no labour? Someone could say that in an absolutely mechanised productive system, production could be obtained without the intervention of labour. Right; but, could capital have existed, in the first place, without the intervention of labour? Therefere, we must conclude, labour is the primary and most important factor of production. Moreover, taking the argument to the limit, it is the only proper factor of production, since the others derive either its existence or its use from it. And if we think about the demand side of the economy; what use would any production —and therefore any factor of production— have, if there were no people whose demand needed te be satisfied?

This is the core of the problem we are dealing with. This is what Professor Simon has had in mind when he has stated that man is "the ultimate resource". Going a bit deeper into the meaning of this expression, Simon has said that the physical finiteness of resources is overcome by the infinite scope of man's imagination. In this sense, resources are not finite from an economic point of view, because they are subject to the infinite potential of discovery, invention and technological progress which the human mind can achieve. A philosopher might object to the use of the term "infinite" in this context. My interpretation of Simon's use of the word is not one of absolute infiniteness, but rather of an apparent one, in the sense that man himself cannot exhaust his own capabilities, the scope of possible human progress.

This idea, as simple as it stands, is a good start for a serious research into the economic consequences of population growth. It is bound to gain wide acceptance, due mainly to its simplicity and obvious adequacy to reality. To quote the World Bank —in its World Development Report 1984—, "...there is little doubt that the key to economic growth is people, and through people the advance of human knowledge".

2) The transmission mechanism

Simon starts by collecting some evidence which might lead him to a restatement of the neoclassical growth theory. Among other facts, he mentions:

i) There are more people alive today than in earlier epochs, and yet most people are better off in most material ways than in the past.

ii) The last 300 years, over which the western world has seen the most rapid population growth in history, have also been the period of the most rapid economic growth in history.

iii) Over the period 1950—1975, while population has grown very rapidly in LDC's, income per capita has also grown very rapidly in those countries.

iv) Throughout human history, technical progress has been faster when population size has been larger (he refers to the cases of Ancient Greece and Ancient Rome at this point).

v) Cross-section contemporary data have also shown that scientific activity is greater in those countries where the population is larger.

According to him, iv) and v) constitute the most important stylised fact that the theory of population and economic growth must fit to. On these grounds, he decides to incorporate technical progress as an endogenous variable into the analysis. Bringing this element into the model implies that the level of technology that is combined with labour and capital in the production function must be influenced directly or indirectly by population, rather than being an exogenous function of time's passage, as it has been traditional in growth theory. The key element in the analysis is that technical change responds in various ways to population size, density and growth.

In trying to explain the process of invention, Simon says that inventions arise from all the possible combinations of ideas that people might have. But, how much productive knowledge can we expect from additional people? Under the very conservative assumption that each new person in the labour force (L) produces only one idea, on average, by successfully combining two old ideas (therefore excluding any idea arising from the observation of the world), the stock of knowledge at any given moment in time would be defined by

$$M_t = \sum_{s=-\infty}^{t-1} J_s + J_t \tag{1}$$

M_t : number of ideas discovered until period t
J_s : number of ideas discovered in period s

The potential number of new ideas that might be discovered at time t is (dropping the time subscript of M) :

$$N_t \approx M\,(M-1) - M\,, \tag{2}$$

and the number of new ideas actually discovered in a given period t will be

$$\begin{aligned} J_t &= L_t\, p(\text{new})\, p(\text{nondup}) \\ &= L_t \{[M\,(M-1) - M\,] / [M\,(M-1)]\} \{1 - [L_t / N_t]\} \end{aligned} \tag{3}$$

p(new) : probability of discovering an idea that hasn't been discovered before
p(nondup) : probability of discovering an idea that isn't being concurrently discovered by another person

The important point to make in this analysis is that the number of new ideas discovered in t is a positive function of L, as can be seen from the following rearrangement of (3) :

$$J_t = L_t \, [\, (N_t - L_t) \, / N_t \,] \, p(new) \; = \; [\, (L_t N_t - L_t^2) \, / N_t \,] \, p(new) \qquad (4)$$

Intuitively (although it can be proved), we can see that $N_t > L_t$, and therefore p(nondup) is positive. Moreover, p(nondup) will increase each year, because in successive years each new idea can be combined with an ever larger number of already existing ideas, and will asymptotically approach 1. P(new) will also do so, since it is increasing in M, but it makes no difference to the analysis. This implies that there are increasing returns in technology creation from additional people, approaching constant returns in the long run, and suggests that additional people imply additional knowledge, without limits.

Simon also presents an alternative explanation of how population growth might affect economic growth via an increase in technical knowledge, by means of a "learning-by-doing" model. The conclusions are qualitatively the same, so we will not go into it here.

3) The basic model stated

The main model, which is based on an earlier one by Phelps (1966), is a steady-state growth model in which technical progress is included as an endogenous variable.

The first assumption is that technical change is proportional to the number of researchers, and these are proportional to the labour force (L) , as expressed in the first equation :

$$A_t - A_{t-1} = a \, A_{t-1}^{\Delta} \, L_{t-1}^{\gamma} \; , \qquad \Delta , \gamma < 1 \; , \qquad (5)$$

where A is the level of technology.

Then, the model is expanded to allow for other independent variables to enter the analysis:

$$A_t - A_{t-1} = b \, L_{t-1}^{\gamma} \, A_{t-1}^{\Delta} \; Y_{t-1}^{\Phi} \; (Y/L)_{t-1}^{\Psi} \; , \qquad \Phi, \Psi < 1, \qquad (6)$$

where Y is the level of income.

Y_{t-1} reflects the fact that bigger economies have more technical progress, and (Y/L) is a proxy for variables such as the level of education and training.

This last equation can also be expressed as (dropping time subscripts again) :

$$A_t - A_{t-1} = b\, L^{\mu} A^{\Delta} Y^{\varepsilon} \,, \tag{7}$$

where $\mu = \gamma - \Psi$

$\varepsilon = \Phi + \Psi$

The output (Y) and savings (S) equation of the model are the following:

$$Y_t = K_t^{\alpha} \, (A_t L_t)^{\beta} \tag{8}$$

$$S_t = s\, Y_{t-1} \,, \qquad 1 > s > 0 \tag{9}$$

K : capital

Next, the exogenous labour force growth:

$$L_t = L_{t-1} + h\, L_{t-1} \,, \tag{10}$$

where *h* is a control variable in the analysis.

In the steady-state equilibrium (where the dots represent proportional changes per period of time):

$$\dot{A} = g_a \,, \qquad \dot{L} = g_L \,, \qquad \dot{K} = g_k \,, \qquad \dot{Y} = g_y \tag{11}$$

(all constant)

Manipulating equation 7, we get

$$(1/\dot{A})\,(d\dot{A}\,/dt) = \mu \dot{L} + (\Delta - 1)\dot{A} + \varepsilon \dot{Y} = 0 \tag{12}$$

So,

$$g_a = [\, \varepsilon /(1 - \Delta) \,]\, g_y + [\, \mu /(1 - \Delta) \,]\, g_L \tag{13}$$

Then, equations 8, 9 and 10 and the long-run equilibrium conditions can be reduced into the following equation:

$$g_a = [\, (1 - \alpha) / \beta \,]\, g_y - g_L \tag{14}$$

From here, we can determine the equilibrium values of g_y and g_a :

$$g_y = \{[\, 1 - \Delta + \mu \,] \,/\, [\, ((1 - \alpha)/\beta)\,(1 - \Delta) - \varepsilon \,]\}\, g_L \tag{15}$$

$$g_a = \{[((1 - \alpha)/\beta)\,\mu + \varepsilon] \,/\, [\, ((1 - \alpha)/\beta)\,(1 - \Delta) - \varepsilon \,]\}\, g_L \tag{16}$$

For the special case of constant returns to scale in the production function, $\alpha + \beta = 1$, and we get

$$g_y = [(1 - \Delta + \mu) / (1 - \Delta - \varepsilon)] g_L \tag{17}$$

$$g_a = [(\mu + \varepsilon) / (1 - \Delta - \varepsilon)] g_L \tag{18}$$

The equilibrium value of the growth rate of per-worker income would be

$$g_{y/L} = [(\mu + \varepsilon) / (1 - \Delta - \varepsilon)] g_L = g \tag{19}$$

This is equal to $g_{y/p}$, where *y/p* is per-capita income, if the growth rate of the labour force is the same as that of the population (P).

Consistence with the equilibrium conditions of the model requires that $\mu + \varepsilon > 0$. Also, the denominator must be positive, because otherwise there would be no equilibrium with positive growth rates of L, A and Y. Furthermore, some simulation calculations show that, for all initial values of *A-dot* , *Y-dot* > 0 , the condition $\Delta + \varepsilon > 1$ causes the system to explode because *dA/dt* and *dY/dt* are positive.

The previous results imply that there is a positive effect of population growth on income-per-capita growth in the steady-state long run. The magnitude of this effect would depend on the values of ε , μ and Δ (the income, labour and technology elasticities of technical change). In simulations, Simon has used values of 1/3, 1/6 and 1/3 for these parameters. With these values, our model would tell us that the steady-state growth of income per capita would be 3/2 times as big as the growth of population.

The model just described presents the unrealistic feature of an ever-increasing rate of growth of income per capita as the rate of growth of population increases. In other words, faster population growth would imply a faster equilibrium rate of growth of the standard of living, without limit, which is -to say the least- "unaesthetic" (to put it in Simon's words). Simon goes on, then, to correct the model, by assuming that the rate of adoption of technology becomes, at some stage, negatively influenced by population size or the rate of population growth. With this new, modified model -which I will not state here-, he arrives to the conclusion that the rate of growth of income per capita converges asymptotically to a long-run fixed value, whatever the rate of growth of population. With the same assumptions for the parameter values as before, he finds out that income-per-capita growth would converge to 3% at very high rates of population growth. For population growth rates lower than 4%, it would always grow (this would be the case for the vast majority of the countries of the world today), except under very restrictive assumptions. In summary, the rate of growth of income per capita would be either growing or converging to its steady-state high-population-growth value –in this case 3%- as the population growth rate increases; it will go over this value only under very special circumstances and, if it did, it will never go below that value as the rate of growth of population increases.

The modified model still supports the main thesis that population growth has a positive effect on the steady-state rate of growth of income per capita, and this is the thesis that we are postulating throughout the rest of this paper.

4) What can the experience of some industrialised countries say about Simon's steady state?

In this section, we take the cases of three industrialised countries –France, Japan and the United Kingdom-, and try to investigate, on the basis of Simon's main model, the length of time that it would take for a country to start benefitting from population growth. These three countries have all undergone different industrialisation processes, with different initial populations and different cultural patterns, and, therefore, we could not expect a priori to get similar results for all of them.

In dealing with the problem, we have extended Simon's model to allow for the possibility of independent variables affecting the growth of income per capita not via population growth but on their own. Our complete model is the following:

$$g_{y/p} = \alpha + \beta\, g_p + \gamma\, r_i + \delta\, r_e + \varepsilon\, d_u \tag{20}$$

$g_{y/p}$: rate of growth of income per capita
g_p : rate of growth of population
r_i : rate of investment, defined as (I/Y)
r_e : rate of education, defined as (S/P), where S stands for students
d_u : change in the rate of unemployment, expressed as a percentage of the labour force

For constructing $g_{y/p}$, the GDP was used for France and the UK, but for Japan it was necessary to take the GNP, since there existed no series of GDP for the whole of the period under study. For the rate of investment, we defined investment as gross fixed capital formation plus change in stocks. As for the rate of education, the number of students S is the sum of all students in primary, secondary and higher education in each period of time. For the UK, r_e was constructed as the rate of education in Great Britain, due to the lack of data for the whole nation during the relevant period.

The unavailability and, sometimes, unreliability of the existing statistical data have constrained our time series to a length of 86 years in the case of population growth (1900-1985) and 40 years at the most for income and investment. These constraints determined the size of the other time series. For a list of the basic data used, see the Appendix.

For the purpose of running the regressions, we have transformed the data into moving averages of five years, in order to smooth the trends of the series. This method proved to have a positive effect on the goodness of fit of the equations. But the tradeoff was the loss of four observations in each series. In the end, we were left with 30 observations (1956-1985) for each regression. This allowed for lags of up to 50 years for population growth, 20 years for the rate of education (unrestricted) and 10 years for the rate of investment.

As it stands, with lagged values of population growth, investment and education, our model looks very much like a production function for the whole economy. For the sake of completeness (and theoretical consistency), we have added the change in the rate of unemployment as independent variable to account for slack demand in some periods, during which the productive capacity in the economy was not used to its full.

The main question, in the analysis that follows, is : How long will it take for population growth, either through creation of productive knowledge or any other mechanism (we will not inquire into the transmission mechanism here), to overcome or, at least, start to offset, the negative effects of capital dilution and increased consumption on income per capita?

a) The case of France

We have started, in every case, by trying as many lags as possible -within a reasonable range- for every independent variable, putting a lower limit of 15 on the degrees of freedom. In this case, however, we have only tested 3 lags for r_i , because the sample was not large enough.

The first equation in Table 1 has a very good fit, as it ought to be. Unfortunately, the Durbin-Watson statistic doesn't tell us very much with so many independent variables. It is possible that there be autocorrelation of first order, although not so likely, since the number is rather close to 2. The most significant variable here is d_u , which has the expected sign. Other significant variables at the 5% significance level are $g_p(-20)$, $g_p(-30)$ -just-, $r_i(-1)$ and $r_e(-15)$, but these last two do not have the expected sign. Overall, it seems to make sense for g_p and d_u , but not for r_e and r_i .

Table 1: FRANCE

Eqn	Meth	Coefficients of independent variables [t-stat]													RSS	F	D-W
		c	$g_p(-10)$	$g_p(-20)$	$g_p(-30)$	$g_p(-40)$	$g_p(-50)$	$r_i(-1)$	$r_i(-2)$	$r_i(-3)$	$r_e(-10)$	$r_e(-15)$	$r_e(-20)$	d_u		[R2]	
1	ols	3.07	1.3	-0.68	-0.73	0.26	0.83	-0.98	0.61	0.53	0.67	-0.95	0.03	-2.99	1.24	51.22	1.7
		[0.44]	[1.64]	[-2.45]	[-1.7]	[.65]	[0.64]	[-2.21]	[1.51]	[0.98]	[1.42]	[-1.93]	[0.12]	[-2.5]		[0.973]	
2	ols		1.1	-0.75	-0.59	0.37	0.91	-0.87	0.62	0.35	0.81	-0.76	0.02	-3.34	1.25		
			[1.73]	[-3.3]	[-2.01]	[1.19]	[0.72]	[-2.46]	[1.54]	[1.02]	[2.31]	[-3.02]	[0.08]	[-4.0]			
3	ols	-7.56	0.16	-0.66	0	0.71	0.27		0		0.77			-4.15	1.7	68.39	1.83
		[-2.3]	[0.39]	[-2.5]	[-.01]	[2.38]	[0.38]		[0.01]		[2.22]			[-5.5]		[0.963]	
4	ols		-0.41	-0.14	-0.09	0.57	-0.28		0.16		0.08			-3.66	3		
			[-1.1]	[-.99]	[-.43]	[1.78]	[-0.39]		[1.16]		[0.4]			[-4.64]			
5	ols	-0.29				0.68			0.13		0.12			-3.85	2.82	95.71	1.02
		[-.22]				[3.48]			[2.58]		[1.03]			[-6.82]		[0.939]	
6	ols					0.7			0.13		0.1			-3.75	2.83		
						[4.34]			[2.62]		[1.41]			[-11.1]			
7	ar1					0.61			0.16		0.04			-3.71	2.15		
						[2.99]			[2.42]		[0.37]			[-8.6]			
8	ols					1.99			-0.04		0.28				16.17		
						[7.5]			[-0.38]		[1.79]						
9	ar1					0.57			0.19		-0.1				4.49		
						[1.72]			[1.28]		[-0.49]						
10	ols					0.91					0.27			-3.47	3.58		
						[5.89]					[38.9]			[-9.8]			
11	ar1					0.77					0.27			-3.56	2.61		
						[3.54]					[23.3]			[-7.3]			
12	ols					0.6			0.19					-3.86	3.06		
						[4.07]			[42.2]					[-11.6]			
13	ar1					0.58			0.19					-3.71	2.15		
						[3.02]			[27.5]					[-3.6]			
14	ols					1.95					0.22				16.25		
						[8.18]					[24.7]						
15	ar1					0.63					0.15				4.75		
						[1.89]					[2.13]						
16	ols					1.79			0.15						18.1		
						[7.15]			[23.3]								
17	ols					1.54									369		
						[1.38]											
18	ols					4.19									324		
						[2.51]											

In the second equation, we have eliminated the constant and thus gained one degree of freedom. The RSS doesn't change very much ; also a good fit . The pattern is very similar to that of equation 1, with almost all the variables gaining in significance. In general, it should be preferred to equations 1.

In equations 3 and 4 we have only included the lags of r_e and r_i that, having the expected sign, seem most significant. Equation 3 is a very good fit, with an R^2 that is very similar to the one of equation 1. The D-W statistic is better, with autocorrelation unlikely. Still, an odd result is the insignificance of r_i . Equation 4, without a constant, is not an improvement.

In the rest of the equations, we have taken the lag of g_p that, having the sign we are looking for, looks like the most significant one. Equations 5 and 6 look excellent, except for the lack of significance of r_e , but equation 5 is affected by autocorrelation. Equation 7 corrects (6) for the possibility of autocorrelation of first order ; there is little change in the significance of the variables. As there is little difference in the RSS between similar equations with and without a constant, we run all the rest of the regressions without a constant, in order to gain one degree of freedom. When you take away d_u , as in equations 8, 9, 14, 15, 16, 17 and 18, the equation loses significance immediately. Equations with only one independent variable, like (17) and (18), are useless, considering that the total sum of squares in this sample is 46. Very good equations are also (10), (11), (12) and (13), which tell as that education and investment are two possible alternative causes of economic growth, apart from population growth. Some equations have been transformed to AR1 processes, to allow for the possibility of autocorrelation of first order.

With respect to population growth, the best fits show us significant positive parameters for 40-year lags of g_p . Moreover, the case of France also shows possible positive effects of g_p with a lag of only 10 years. The capital-dilution and excess-demand effects would be dominant only between 20 and 30 years after the population increase, and the positive effects would start dominating after 40 years.

b) The case of Japan

This case should particularly attract our attention, since both economic growth and population growth have been significantly higher in Japan than in most European countries over the period studied.

Table 2: JAPAN

Eqn	Meth	Coefficients of independent variables [t-stat]															RSS	F	D-W
		c	$g_p(-10)$	$g_p(-20)$	$g_p(-30)$	$g_p(-40)$	$g_p(-50)$	$r_i(-1)$	$r_i(-2)$	$r_i(-3)$	$r_i(-5)$	$r_i(-6)$	$r_e(-10)$	$r_e(-15)$	$r_e(-20)$	d_u		[R2]	
1	ols	-51	-0.81	0.12	-0.08	0.74	-0.35	-0.53	-0.08	0.17	-0.17	-0.11	2.9	-2.7	3.44	-12.4	3.34	79.31	2.38
		[-5.1]	[-1.5]	[0.26]	[-0.16]	[0.93]	[-0.18]	[-2.2]	[-0.24]	[0.66]	[-0.62]	[-0.38]	[8.11]	[-9.0]	[4.42]	[-4.2]		[0.99]	
2	ols		0.07	0.96	1.78	1.54	0.63	-0.04	0.19	-0.02	0.64	-0.58	1.91	-2.5	0.35	-10.3	9.23		
			[0.08]	[1.35]	[3.3]	[1.21]	[0.21]	[-0.11]	[0.36]	[-0.05]	[1.72]	[-1.3]	[3.93]	[-5.2]	[0.44]	[-2.18]			
3	ols	-34	-0.05	1.27	0.18	-3.3	9.7			-0.41			1.9			-6.27	28.13	20.73	0.99
		[-4.6]	[-0.07]	[2.03]	[0.32]	[-2.08]	[2.88]			[-5.0]			[5.47]			[-1.21]		[0.89]	
4	ols		-1.8	0.77	-0.85	-1.77	2.08		-0.22				0.72			-22	57.26		
			[-2.1]	[0.9]	[-1.1]	[-0.82]	[0.5]		[-2.2]				[2.29]			[-3.8]			
5	ols	-20			1.05					-0.17			1.37			-7.04	48.42	26.07	0.39
		[-3.6]			[1.74]					[-3.0]			[5.95]			[-7.04]		[0.81]	
6	ar1	-12			0.24					-0.16			1.06			-6.11	14.49	7.65	1.6
		[-1.6]			[0.59]					[-1.8]			[3.16]			[-2.13]		[0.56]	
7	ols	-23					6.4			-0.29			1.36			-6.42	44.2	29.14	0.41
		[-4.1]					[2.38]			[-3.7]			[7.12]			[-1.63]		[0.82]	
8	ar1	-13					1.48			-0.19			1.06			-6.7	14.51	7.94	1.6
		[-1.6]					[0.59]			[-1.9]			[3.23]			[-2.5]		[0.57]	
9	ols			1.11					-0.16				0.48			-15	72.25		
				[1.88]					[-2.5]				[5.07]			[-3.03]			
10	ar1			0.42					-0.2				0.54			-7.77	14.42		
				[1.09]					[-1.9]				[3.62]			[-2.9]			
11	ols	-26					7.97			-0.37			1.48				48.88	35.72	0.49
		[-4.5]					[3.08]			[-6.5]			[8.05]					[0.81]	
12	ols	-13								-0.15			1.08			-9.79	54.25	31.33	0.3
		[-3.4]								[-2.7]			[6.6]			[-2.44]		[0.78]	
13	ols	-15											1.02			-17	69.19	35.34	0.37
		[-3.8]											[5.7]			[-5.3]		[0.72]	
14	ar1	-13											0.9			-7.3	15.98	10.83	1.5
		[-1.7]											[2.53]			[-2.8]		[0.46]	
15	ols	9.93								-0.1						-15	144	9.89	0.18
		[-4.0]								[-1.11]						[-2.4]		[0.42]	
16	ar1	9.1								-0.1						-6.6	18.6	6	1.32
		[2.4]								[-0.81]						[-2.3]		[0.32]	
17	ols	18					-8.7										194	8.16	0.15
		[4.5]					[-2.9]											[0.23]	

The equation with all the variables and lags is again an excellent fit ; autocorrelation is unlikely. Negative and positive parameters for g_p alternate, but none of them is significant. Another odd thing is that all the parameters for r_i are negative, except for the 3-year lag, which is not significant anyway. The variable d_u , as always, is clearly significant, and r_e has two very significant lags for the expected sign. Equation 2 eliminates the constant, but the fit clearly deteriorates. It shows only positive effects from population growth, which is rather unlikely.

Equation 3 is not a bad fit, but autocorrelation is very likely. Here we have taken the most significant lags –among the ones with the expected sign- for r_i and r_e . Equation 4 is similar to (3), but without constant. The fit isn't so good.

In the rest of the equations, we try to eliminate some lags and some variables, without very satisfactory results for g_p . What can be seen throughout is the importance of r_e in this case, which always appears significant with a lag of ten years. We might conclude that in a country like Japan, with few natural resources, investing in people seems to be an especially good policy. Another interesting point to make is that eliminating d_u does not affect so much –as in the case of France for example- the goodness of fit. This is due to the fact that unemployment has hardly changed over the last 35 years in Japan, particularly if we measure that change by western standards.

For the purpose of our investigation, we should stick to equation 1, which is the best fit. We certainly wouldn't be able to tell when do the positive effects of population growth become dominant. But what looks very likely is that the negative effects are dominant –if at all- only during the very first years after the population increase.

c) The case of the United Kingdom

The UK would seem, at first, an unattractive case, due to the sluggishness of both its population and economic growth over the period under study. And yet it is bound to show very clear and interesting results.

Equations 1 and 2 are good fits, as expected; but not as good as were the equations for France and Japan with all the variables and lags. In equations 3 and 4, we have chosen lags for r_e and r_i , but none of the variables, except d_u, looks very significant. The fit is not bad; probably better for the equation without a constant. Autocorrelation is not very likely. The most significant positive value for the coefficient of g_p is given by the 40-year lag, so we adopt this lag for the rest of the equations.

Table 3: UNITED KINGDOM

Eqn	Meth	Coefficients of independent variables [t-stat]															RSS	F	D-W
		c	$g_p(-10)$	$g_p(-20)$	$g_p(-30)$	$g_p(-40)$	$g_p(-50)$	$r_i(-1)$	$r_i(-2)$	$r_i(-3)$	$r_i(-5)$	$r_i(-10)$	$r_e(-10)$	$r_e(-15)$	$r_e(-20)$	d_u		[R2]	
1	ols	11.7	0.39	-1.4	0.78	-3.1	-1.39	-1.2	0.06	0.75	-0.18	-0.07	0	0.69	-0.29	-2.46	0.52	27.27	2.28
		[2.82]	[0.37]	[-1.16]	[0.73]	[-3.7]	[-1.6]	[-5.4]	[0.19]	[3.09]	[-0.78]	[-0.77]	[0.0]	[4.58]	[-2.4]	[-6.23]		[0.96]	
2	ols		-0.8	0.87	0.08	-2.3	0.82	-0.81	0.24	0.41	0.06	-0.18	0.25	0.39	-0.06	-2.74	0.79		
			[-0.69]	[0.85]	[0.07]	[-2.4]	[1.7]	[-3.9]	[0.72]	[1.64]	[0.23]	[-1.7]	[1.11]	[3.06]	[-0.55]	[-5.98]			
3	ols	2.09	-0.78	-0.06	-1.54	0.76	0			0.13			-0.09			-1.14	2.67	10.85	1.76
		[0.94]	[-0.56]	[-0.05]	[-1.11]	[0.62]	[0.0]			[0.88]			[-0.43]			[-3.47]		[0.81]	
4	ols		-0.23	0.49	-1.27	0.97	0.46			0.11			0.01			-1.59	2.78		
			[-0.18]	[0.49]	[-0.94]	[0.81]	[0.82]			[0.75]			[0.08]			[-4.42]			
5	ols	0.88				0.9				0.1			0.7			-1.45	2.98	22.49	1.49
		[1.11]				[1.46]				[0.21]			[0.72]			[-5.58]		[0.78]	
6	ols					1.06				-0.01			0.15			-1.64	3.14		
						[1.76]				[-0.12]			[2.16]			[-8.36]			
7	ols					1.07					0		0.14			-1.62	3.13		
						[1.82]					[-0.01]		[2.49]			[-10.3]			
8	ar1					1.04					-0.01		0.15			-1.62	3.05		
						[1.6]					[-0.16]		[2.3]			[-8.69]			
9	ols					1.07							0.14			-1.62	3.13		
						[1.89]							[7.37]			[-10.9]			
10	ar1					1.05							0.14			-1.62	3.05		
						[1.67]							[6.63]			[-9.2]			
11	ols					1.79					0.09					-1.46	3.88		
						[3.19]					[6.21]					[-9.35]			
12	ar1					1.59					0.1					-1.44	3.62		
						[2.33]					[5.28]					[-6.93]			
13	ols										-0.01		0.19			-1.71	3.53		
											[-0.32]		[3.73]			[-11.15]			
14	ar1										-0.02		0.2			-1.73	3.32		
											[-0.38]		[2.98]			[-8.64]			
15	ols					5.08										-1.1	9.42		
						[17.9]										[-4.95]			
16	ar1					4.43										-0.83	6.7		
						[8.46]										[-2.27]			
17	ols										0.17					-1.7	3.54		
											[30.0]					[-11.6]			
18	ols					4.24											17.67		
						[13.8]													

Equation 5 still doesn't show us very significant coefficients. Eliminating the constants, as in equation 6, gives significance to g_p and r_e , while still maintaing a good fit.

Equations 7 to 15 are all very interesting, because they show us the relative importance of the different explanatory variables, with good fits throughout . (7) and (8) show us that r_e is significant, but r_i is not . When we eliminate r_i , as in (9) and (10), r_e increases its significance notoriously. On the other hand, if we eliminate r_e and maintain r_i , as in (11) and (12), it is r_i which looks very significant, although not as significant as r_e in (9) and (10). This shows us, the same as in the case of France, that education and investment are alternative possible causes of growth. g_p remains significant throughout this process. If we eliminate it , as in (13) and (14), the significance of r_e is increased and the coefficient of r_i is negative, but not significantly. This indicates that r_e might be acting as a proxy for g_p , which is logical, if we consider that r_e measures the "quality" of the people, as compared to the amount of people, measured by g_p .

The rest of the equations are not very good fits, except for (17), which tells us that if only two variables were to explain economic growth, they would be r_e and d_u .

In summary, we could say that in this case, although g_p doesn't look very significant throughout, it seems likely that positive effects of g_p on $g_{y/p}$ will start to dominate after 40 years of the population increase.

5) Summary and conclusions

We have tried to measure the amount of time that separates population growth from its beneficial effect over economic growth, as described in the models of Julian Simon. The task has not been easy, due to the poor quality of the statistical data available, and is far from accomplished. This paper aims to be a first step in that direction .

It is very clear that the analysis has many limitations. To mention one, we are assuming that, if population growth affects economic growth in the way Simon describes, technological transfer is not very significant. Otherwise, population growth in one country could affect economic growth in others –most probably this happens to a considerable extent . This possibility is not ruled out by Simon's theory; only by the type of empirical analysis carried out in this paper.

This econometric analysis is just a first attempt to point out certain relevant features of the process of economic growth of some countries; specifically France, Japan and the UK . I am sure it can be developed in many more directions and answer many questions which here are left unanswered.

One of the questions which might arise is about the length of time it would take for the positive effects of population growth to offset the previous negative effects, and therefore start rendering dividends, to put it in accounting terms. I will try to give some hints towards the answer. If we take the case of France, for example, we could work with equation 3, which is the best among the ones with all the lags for g_p and the best lags for r_e and r_i . If we calculate the effects of g_p over $g_{y/p}$, we find out that we would be better off after 40 years with a positive population growth than with zero population growth. The improvement in the case of France –with g_p of only about 0.5%- is very small, but it will be higher the higher is g_p . For Japan and the UK –taking their equations 3 and 4, respectively-, the result that we are looking for works out to be between 40 and 50 years.

Another question left unanswered refers to the measurement of the length of time during which population growth affects economic growth, before its effects die out. If we knew this, we would be able to measure the total effect of population growth over economic growth. I am afraid, though, that many years will have to pass before the statistical data permit to carry out this type of analysis.

Nevertheless, some clear conclusions can be drawn from the analysis carried out in this paper. First, that one can detect positive effects of population growth over economic growth before 50 years, and sometimes as early as within ten years, as we have seen in some cases. Second, the model presented by Professor Simon needs to be extended for the purpose of empirical analysis. We have seen that the model with only one independent variable shows very little econometric significance, for the cases analysed in this paper. And finally, it is necessary to point out the importance of investment in human capital, as measured by education here, in the process of economic growth. In most of the regressions, the rate of education proved even more significant than the rate of investment (in physical capital). So, as suggested earlier, it is not only the quantity of that “ultimate resource” which matters, but also its quality.

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