Theoretical Framework for a Unified Model of Population and Economic Growth

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Introduction

There is a marked difference in the models of technological and economic growth proposed by Malthus (Malthus and Smith 1798) and later Solow, which allow for no per capita growth of income as capital is fixed. However, later models do allow for per capita economic growth and appear to fit the observable conditions in the recent past. The Malthusian model is considered accurate in pre-industrial societies but fails to work correctly in industrialized environments. To reconcile the differences between the two fundamental environments, some have created multiphase models which allow for Malthusian, Post-Malthusian and finally Modern regimes, (Galor and Weil 1998) whilst others such as Simon-Steinmann (Simon 1986) have created two models, one for each of the two stylized regions named the More and Less Developed Countries (MDC and LDC respectively) (Simon 1977), effectively treating the two groups as distinctly separate. The rational behind this distinction is that a "demographic transition" has occurred in one (the MDC) and is now beginning to occur in the LDC nations but under different circumstances. Most of these circumstances are economic in nature and the tacit assumption is that economics is the driving force behind the transition and not the other way around as has been suggested by Knodel and van de Walle (Greenhalgh 1995). In the case of Galor-Weil model, there appears to be an assumption that today's economic world is different from the one that Malthus observed. Simon does not explicitly make this assumption but also does not deal with historical perspective any earlier than the industrial revolution other than anecdotal evidence of Greece and Rome in "*The Ultimate Resource*", in part due to lack of economic data.

Assuming that today's economic environment is operating using the same mechanisms as before, there is a question that needs an answer. Do current growth models accurately portray not just trends of population and economic growth but also elucidate the mechanisms by which the economic growth occurs? Based on the need for multi-phase models and separate handling of different types of economies, there is a good chance they do not. As well, Simon dismisses the effect of demographic anomalies on the short-term economics of nations in favor of long-term trends. He specifically dismisses the impact of age-structure and dependency ratio on economic growth as minimal compared to that of the level chosen for the savings rate (Simon 1977). What he does not deal with is the possible effect the age-structure and other demographic dynamics may have on the savings rate.

Assuming there is a demographic effect on the level of investment, then it only stands to reason that these population dynamics have an effect on the short-term and long-term economic growth of the economy. Due to speed of the current demographic transition in LDC nations, these effects may be exacerbated and causing current observable conditions to appear different from those conditions leading to the wealth of the MDC nations.

Using a simplified illustration based on current anthropological theory, the framework for the link between population growth, population size, carrying capacity of the land and economic growth will be explored. This possible link may also help elucidate some of the possible mechanisms for economic growth; something which Simon does little of as he tends to approach the subject from the standpoint of having the model match known trends.

Simon-Steinmann Economic Growth Model

The basic idea to the theory proposed by Julian Simon and Gunter Steinmann is that the greater the total population, the greater the level of technological growth yielding greater per capita income. An idea derived from Boserup (Simon 1977), which Simon refers to as the "Population Push" model, and distinguishes between current knowledge and knowledge being applied for production.

Underlying the population push model of technological development is the added idea that technology can and does develop independent of population growth (learning-by-doing) and therefore technology builds upon itself, reconciling the pull and push models of technological progress. So even in the case of a static population, there will be some level of technological advancement, albeit slower than in situations of growing population. It is just that necessity remains the mother to, and is the primary force behind, invention. This technological progress function is added to the Douglas-Cobb production function to produce a model containing endogenous technological progress based on population growth and learning-by-doing. One other aspect of note in his model is that labor supply and population are used synonymously as he dismisses the impact of age-structure and dependency ratio on economic growth as minimal to the effect of the savings rate. He uses Japan and the US as an example of the disparity between savings rate and the effect it has on output (Simon 1977).

The results of the model yield modest per capita economic growth at equilibrium and Simon determines that maximized long term economic growth (always in per capita terms unless otherwise noted) requires 1-2% per annum population growth and a 2-4% rate of savings with a low discount rate below 4%. At a higher discount rate of 5-10% there was still increased consumption. This population growth rate, he makes clear, is higher than the rate that produces the highest adoption of technology (Simon 1986). Any growth that occurs too fast will have diminishing returns or create a circumstance where growth is stagnating. As well, modest negative population growth will have the effect of limiting growth but large negative out flows in population will stagnate growth outright. The level of total technology (available and in use) never decreases since this is, in his estimation, illogical. (Simon 1986)

Analysis

When compared to the observed data for the globe[1] (1967-1997) there are mixed results. Globally, per capita GDP did rise, invalidating Malthusian theory, but not equal to or faster than population growth diverging from Simon's work somewhat. However, Simon does concede to some short-term impact to population growth in his model but

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[1] I did this for a paper where I compared Nordhaus' Dice model with the fixed technological progress function and Simon's Endogenous technological progress function.

contradictory evidence has suggested that wages are affected minimally in the short term by a sharp increase in population (Friedberg and Hunt 1995). This contradictory evidence may not mean all of Simon's work is invalid. In that work much of the increase in population may have increased the labor supply a greater proportion than the increase in the overall population, as migration rates are generally much higher for those between the ages of 20-50 (labor age groups) than for other groups. This may mean that there may be a rather interesting and complex relationship between population growth (and the resulting dependency ratio) and the savings rate. It is this relationship that will be explored and the framework of an alternative model with an endogenous savings rate reflecting demographic growth and density along with resource quality factors and technology transfer expenditures will be proposed through a theoretical perspective. These factors also need to be reflected in the handling of "technology" where total population numbers increases available technology while density and resource quality factors affect the demand on technology, referred to as the level of technology in use. Finally, transfers of technology between MDC and LDC nations, as suggested by Galor and Weil (Galor and Weil 1998), and handling of migration when implemented will allow for one model to handle both open and closed economic systems. Hopefully when all modifications are implemented a single truly unified model can be developed.

Valued-Added Services

One of the most general implications of Simon's model is that economic growth is tied to the scarcity of resources. The more scarce resources are, the greater growth in economic output per capita. In other words, it could be stated that economic growth is the measure of the value added services needed to bring natural resources to the market for consumption[2]. Extending this concept, as the natural resources initially consumed, lets suppose at the birth of a fictional society, became more and more scarce as population grew, the substitutes employed to respond to the demand were less than perfect. I will illustrate using wood as an example. In the beginning, wood would have been readily available with simple gathering techniques as trees die, lose braches, etc. The gathering would be considered the value added service. If demand (population) rose, the amount of gatherable wood may not be a sufficient supply to satiate demand. Here improvements in technique would allow for the harvesting of non-gatherable wood by the creation of the ax. Let's suppose the ax was initially created earlier in time by a tinkerer who collected a large fallen branch and realized there was a way to break it apart, signifying available technology. Creating the ax out of wood and stone would be the first step (known as technology available) and the application of it added it to the level of technology in use. The manufacturing of the ax uses the resource demanded and a new resource to facilitate a greater supply of wood. It is also a value added service that is now added to the economy. The total economic output is then the summation of the gathering of naturally fallen wood and wood felled by harvesters, the felling of the trees to harvest said wood, and the manufacturing of the ax as implement for said felling. Capital would be a combination of technique and the axes needed for harvesting minus the depreciation of the axes. The ax and technique of harvesting is a less than perfect substitute as in this

[2] Analysis of World Bank data on economic factors show that throughout the world, services (as opposed to goods) are accounting for greater and greater percentages of GNP.

case it required more labor to implement[3]. One could continue this to the present time and would undoubtedly come up with an interesting historical perspective on the evolution of technology. This simple story also illustrates that Malthusian theory is, and probably always has been, wrong lest anybody fails to realize that the capital in use at the time of Malthus did not magically appear out of thin air.

The *implications* of Simon's model do seem to be historically plausible and fit well within the logical framework of a model needed to gauge economic demand. Areas of his model that fail to fit well within a logical framework are his dismissal of the dependency ratio, population density and carrying capacity and finally he links technology in use and technology available both to labor supply size (Simon 1986).

Dependency Ratio and Technology in Use

Using the same example let's explore the issue of dependents and their ratio to producers. Assume that the society mentioned was on an island and had no possible migration route to new resources. Resources continue to become scarce and there arises a need for specialization in services to increase efficiency. There is slow, steady population growth so the age structure remains steady. Infant mortality then drops to half its original level and a large number of children survive through to maturity[4]. The number of people needed to care for the children rises and each child requires some wood as a resource. Although this is a smaller amount than what is required by an adult, the demand for caretakers removes people from the ability to harvest and gather wood effectively offsetting their lower marginal demand by lowering the overall productivity (through immediate production capability) of the society. In the short term the labor force has decreased but the number of consumers has increased. As well, the population has begun to rise. Since improvements in technique are not immediate, the currently available workers are required to perform greater amounts of labor, through increased hours, to continue to support the population. Those increased hours take away from the amount of R&D (tinkering in this example) that is normally done and therefore, at the very least, fails to increase capital and possibly decreases capital. This is because the research is the investment in the future that the savings rate signifies. Effectively the demand on supply in this case has created a situation where the producers are struggling to keep up with offsetting depreciation of capital (replacing worn axes) and continuing to supply the needed resources. In doing so they have neglected the investment into research (suppose being too tired at the end of the day to tinker) and have as a consequence failed to increase both technology available and technology in use. In Simon's model, since labor and population are synonymous, there appears to be no handling of this issue despite a clear effect on the economy. The change proposed here would be to increase the amount of technology available using the size of the population but keep implemented technology a function of labor supply. Using Simon's rationale of "Einsteins and Mozarts", the children being cared for, and naturally educated, are observing the world around them and are adding untested theories to the pool of knowledge (similar to this term-paper). However, their inability to effect production with their newfound knowledge precludes

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[3] Remember that gathering is still needed for harvested trees, and in fact the amount of labor to gather the harvest is likely to be the same, as the weight of the tree and the process of breaking it apart demands labor as well.

[4] Don't look at this as the "Demographic Transition" as I needed an excuse to change the dependency ratio.

that knowledge from being tested and added to the technology in use (again, similar to this term-paper…).

Population Density, Growth and the Carrying Capacity

The next change to occur to our fictional society is that the fertility rate has declined to match the mortality rate, bringing the Net Reproduction Rate to a positive number slightly above one (This way it matches observed population trends in both pre-history and current MDC nation averages). For reasons that will become clear later on, the reason for this decline is irrelevant to the model in both theory and practice (this assumes that a tendency for equilibrium exists and people will try to hover just above zero population growth). As time moves on the dependency ratio evens back out, lets say at 1 to 1. Some of the technique "discovered" by the one younger generation has been added to the technology in use as the immediate pressure on human capital had begun to subside. The productivity of each worker has been raised, allowing for testing and validation of the aforementioned theory. This could be expressed as an increase in the savings rate. As a result, workers have no problem meeting demand, except that it is discovered that the net number of trees on the island has begun to decline, as the harvest is un-sustainable and adding more workers would only lower the marginal productivity of each additional worker. In response, a greater level of specialization has arisen where workers now harvest trees, care for and educate young, and more importantly some of the labor force has begun to look for ways of more efficiently using trees while others have begun looking for more supply. This greater specialization has also led to a need for a specialized government instead of the tribal elders to oversee allocation of resources and make sure resources are flowing to the families of researchers[5].

Some have come to realize that a spot on the horizon may in fact be another island, similar to itself. It has been a theory floating around for a while but the total surplus of resources (NOT surplus per capita as that has decreased as efficiency has risen) and technological ability has not been there for exploration. Since the society has grown there are sufficient numbers of researchers devoted to the issue, despite the percentage of the labor force devoted to research over time has *not* changed, to begin building a small boat with some of the surplus. The population *size*, and therefore increased density, has allowed for the critical mass needed to raise the total level of labor and resource capital needed to explore.

Upon exploration, an island of equal size but half the carrying capacity has been discovered. Carrying capacity is defined here as the number of humans per squared unit of measure able to be sustained given a theoretical baseline level of technology. This measures the level of biotic ability (think potential energy) of the land. This can only be reduced through pollution, destructive deforestation (one that precludes re-growth), desertification or covering of the land. Resource use is not considered able, on its own, to decrease the carrying capacity permanently as more trees would be able grow in place of those lost. However, it does have an immediate effect that is not reflected in the model's application of carrying capacity.

It is decided that a third of the population is to migrate to the new island leaving a 2 to 1 ratio between the populations of each island. The age structures remain the same as

[5] Based on established, albeit not universally accepted, anthropological theory. Followers of Franz Boaz reject many concepts of evolution in culture. See Appendix for more information.

migration affects each cohort equally and both fertility and mortality are the same in both populations at the time of the migration event. After the migration is completed the per capita output of both islands is exactly the same as a third of the capital was transferred in the migration and per capita resource consumption is the same. This fits Simon's logical framework since the level of technology (available and in use) never decreases, since this is, in his estimation, illogical (Simon 1986). What neither his logical framework nor this framework deals with is whether it is per capita technology or total technology that cannot be decreased. An answer is not readily obvious but one idea would be to let the level of per capita technology not decrease but total technology could.

After this migration event, there is relatively little trade and some communication between islands. The second population also drops some of its specialization and the government structure becomes a bit more informal than it had been. There is again sustainable development in both places for a while but since the net reproduction rate is slightly positive resource pressure does begin to creep up. However, the available minds in the original population doing research is double that of the new island's population[6]. This leads to better resource utilization earlier on the old island and the population begins to swell as mortality on the original island declines. This adds resource pressure as population begins to swell at a somewhat higher rate but with out having a huge impact on the dependency rate. The savings rate decreases somewhat as capital is used to invest in more research and new techniques and resources. Each of these techniques being a less than perfect substitute requiring more labor or resources of a different, more labor intensive type and therefore adding more value added services to the production. This continues to add to the total output at a higher rate than population growth, raising per capita output as a result. The same process is not occurring on the new island because they had found another island past them to migrate to when things got tight on resources. The tightening of resources was also due only to the original population growth rates that were originally in place and not through increases to the NRR due to any resource enhancements. As a result, the time needed to reach the next resource threshold was substantially increased.

Technology Transfer

Eventually someone comes up with a medicine on the original island that lowers mortality even further than before effectively putting the mortality rate at half of the original rate at the time of the migration event. Over time the fertility again responds in kind, regardless of reason and the net reproduction rate comes back into line with a positive number slightly above one. Due to the increases in technology and the total surplus of resources (again not per capita surplus of resources), it is decided that the population of the new island can and should benefit from the wonderful new medicines and life-saving techniques discovered on the original island. The medicines are delivered using technology based on the original boat technology developed but has been approved through the process of learning-by-doing. Due to the phenomenal success of the new medicines, the mortality rate rapidly declines and the population of the new island increases at a rate never seen before. However, the density of the island is still far below what the original island is at currently. The new inhabitants quickly begin to burn through

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[6] Keeping in tradition with the "Einsteins and Mozarts" theory of Simon's.

the available sources of wood and as a result of the explosive growth, therefore the unfavorable dependency ratio, the inhabitants of the new island are doing everything they can to keep up with the increasing demand and have no resources for research in new technology.

Unbeknownst to the inhabitants of the original island at the time they offered the life-saving medicines they were actually creating a market for other technology they had long since perfected as a result of resource pressures on their own island. This particular technology, named coal, replaced wood as a fuel source leaving wood useful for building tools such as axes, boats and shovels. Since it is clear that the wood will run out, there is a decision made by the tribe elders that wood will no longer be used as fuel but manufactured into goods to be traded to the original island for coal, as there are no known sources of coal on the new island. So the inhabitants of the new island trade for coal imported from the original island with axes, boats and shovels (used by the original islanders to mine coal) made from the wood they do harvest, as their labor factors are lower than that of the original island. As a result of their lower wages, they are working the maximum number of hours producing goods in trade for coal and harvesting the requisite raw materials needed to produce those goods. Therefore they are keeping up not only with their own demand but that of the demand from trade. Due to the situation as described in the section Dependency Ratio and Technology in Use, there is very little extra output for investment and the available capital is very low as the explosive growth has sling shot the new island society generations past their available technology level in resource demand. So the new island inhabitants are increasingly looking to the old island inhabitants to augment their knowledge of established knowledge and for new techniques, all of which come at a cost. This makes their society reliant on the capital and research of the larger, more sophisticated society and its greater store of knowledge. Eventually fertility comes back in line with mortality and the new island society begins to have the capability to increase its investment in new technology built upon the technology transferred at a cost from the original island. The result is a surge in economic output sometime after the end of the demographic transition. This matches the long-term economic gains seen in the current models and observed in the MDC nations and attempts to reconcile Simon’s use of two models through a technology transfer function driven by highly accelerated population growth in low density, low capital societies matched with investments from high density, high capital societies.

Conclusions

In conclusion, there is most likely a link between the demographic phenomenon of the age-structure effect and short-term economic growth. It most likely effects the adoption and transfer of technology through capital investments or lack thereof when the dependency ratio is high due to a significantly higher than normal net reproduction rate or a significant short-term reduction in fertility that results in an elderly population. Simon’s assertions that steady population growth is even more beneficial to long-term economic growth are probably correct.

As for modifications to the model’s framework, it is argued that his technological progress function should increase the amount of technology available using the size of the population. Newly implemented technology should remain a function of labor supply growth, capital investments and depreciated available technology. Finally, the savings rate should not be fixed but be set endogenously as a function of the dependency ratio (influenced by positive and negative growth rates) and the density of the population adjusted by a resource quality factor derived from the carrying capacity of the environment. In other words, the higher the density of the population, it is assumed the greater demand on resources above the baseline carrying capacity and therefore the higher the savings rate. This is then adjusted for the dependency ratio where the higher the dependency ratio, the greater negative impact it has on the level of investment at that time.

This variant should handle a closed system well but in order for the model to reflect an open system, or model a nation within the world economy, a few modifications have to be made, namely technology transfer needs to be added. With increases in demand that are based on large, short-term increases in the dependency ratio, the technology transfer factor should increase. This should be considered investment that increases the amount of technology in use and increases capital. With decreases in the dependency ratio, the technology transfer fact should reflect returns on investment and add to the capital of the donating nation. Setting this factor to equilibrium would allow this model to be run on a closed system.

The above example lays out a logical framework based upon modern anthropological theories regarding cultural evolution (See Appendix) that reflect links between population growth and socio-political system as Simon has suggested may help (Simon 1997). However, his rational for this link was that socio-political institutions effect economic behavior. There is some thought on the subject as Sahlins, Service and Harding (Sahlins, Service et al. 1960) have suggested that Marxist economic policies serve, in part, as an efficient technology transfer mechanism for bringing a pre-industrial nation up to the level of the industrial nations quickly. This suggests that there are many things that can be influenced by an interdisciplinary study of population and economic growth.

Appendix

In 1997 Simon wrote in the preface of a compendium on the topic of population and economic growth (Simon 1997) that more research was needed into the link between population and socio-political changes. He postulated that socio-political institutions probably have a large effect on the way societies deal with economics and that should be incorporated into the discourse on the subject. Unfortunately modern anthropological knowledge of the evolution of culture and the links with population size and density has been around for at least the time that Simon had been writing on the issue but due to a split between anthropologists, two camps have been struck on the issue.

Those who follow Franz Boaz have advocated against the idea of cultural evolution due to the misuse of the concept by Social Darwinists and others looking to exploit "lesser developed" cultures through the misguided belief that technologically advanced societies got that way through better genetics. The other camp has no leader but can be seen in the writings of Marshall Sahlins, Leslie White and others across the United States. Shepard Krech (Krech 1999) illustrates in his book, "*The Ecological Indian*" that many Native American societies, despite having inferior technology compared to white settlers, were beginning to advance in technology in familiar patterns. His conclusion is that Native Americans were well on their way to accomplish what westerners had if given the required time, keeping in mind their presence on the continent was 20-15,000 years old while Europeans were around at least 33,000 years. There is also evidence that some tribes in certain times were yielding returns as high as agriculture that Western European Whites descendents did not reach until the 20^{th} century.

It is with these and other principles the above example was crafted to illustrate in one story what some believe is the story of development, failed and successful, of human societies. Along with these theories come some assumptions and criticisms of economic theory. The first is that one economic measure that is often bandied about is standard of living and that is NOT to be synonymous with quality of life in this discussion. Another assumption is that being in a hunter-gather society, represented by low capital and per capita output, is not synonymous with having a low standard of living OR quality of life (Sahlins 1972).

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