Food Security and Population Growth in the 21st Century

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Does population growth affect food production? Does this effect vary across regions? Scholars have proposed food insecurity as one of the threats that society will endure during this century. Global population has grown exponentially. Current numbers are estimated around 6,692,030,277(World Bank, 2009) and are expected to rise 9.3 billion in 2050. The world's population will double in the next 50 years, if the current growth rate of 1.3 percent continues (Kendall and Pimentel 1994:198). However, world cereal yields and agriculture production have declined since 1961 (Harris and Kennedy, 1999). According to FAO, per capita food production declined in 51 developing countries, while rising in only 43 between 1979 and 1987 (Sadik, 1991).

This study examines the relationship between agriculture growth and population growth rates in countries around the world. In particular, this paper seeks to identify the difference in the relationship between population growth and agricultural growth among the following regions: Africa, Asia, Europe, North America, Latin America and Oceania. The paper begins by reviewing the current literature relevant to the Malthusian theory of scarcity and agriculture production. It continues by developing a theoretical framework in which I suggest that population growth is increasing at a higher rate than agriculture production. I test this hypothesis by analyzing agriculture production, population growth and economic development data from all countries from 1981 to 2008. The paper concludes with a discussion of the results of the regression on agriculture production and a summary of future research needs.

Food Insecurity

Magadoff and Tokar (2009) concluded that 12% of the global population –approximately 36 million people- suffer from hunger and live without secure access of food. Decreased food production in less developed countries, increases in the price of food, and growing production of bio-fuels are responsible for current rates of food scarcity. Global warming, crop diversity loss and urban sprawl also affect agriculture production. Kendall and Pimentel(1994) note that current per capita grain production seems to be decreasing worldwide. The situation is particularly distressing in Africa, where grain production is down 12% since 1980. Africa only produces 80% of what it consumes (Kendall and Pimentel, 1994:199)

For most countries, population growth rate is approximately 2-3% a year, which should translate to an annual increase of 3-5% in agriculture production levels. (Kendall and Pimentel, 1994: 202) Kendall and Pimentel designed three models to predict crop levels by 2050. They concluded that if production continues at its current rate, per capita crop production will decline by 2050. The possibility of tripling today's current crop production is unrealistic (Kendall and Pimentel, 1994).

Food insecurity has the potential for worsening far beyond anyone's expectations. Have we finally reached Earth's carrying capacity? Scholars' opinions vary depending on their perspective. While Neo-Malthusian scholars such as Paul Elhrich(2009) believe that the only way to avoid this catastrophe is by restraining population growth, others such as Rusell Hopfenberg(2003) assert that we must curb food production to limit population growth.

Neo-Malthusian Model

Thomas Malthus(1806) was the first to address food scarcity as an issue and defended the hypothesis that growing global population will eventually eclipse the Earth's capacity to feed it. "The power of population is indefinitely greater than the power in the earth to produce subsistence for man."(Malthus, 1806:13) Erhlich extended Malthus' theory on population growth by asserting that humans were going to fail in the battle against hunger. Despite his predictions, Erhlich recognized that the some societal shifts have occurred that indicated that at least some populations were slowing their growth. For instance, fertility rates in most developed nations have dropped to less than replacement levels and the Green Revolution had a larger impact than expected (Ehrlich, 2009). However, the absolute number of people without enough to eat in 2005 – approximately 850 million – was similar to the number reported in 1968 (Elhrich, 2009)

Quinn (1997) questioned Malthus' Scarcity theory by proposing that increases in food supply are responsible for population growth. Scholars as Rusell Hopfenberg(2003) have supported this hypothesis. Hopfenberg (2003) determined Earth's carrying capacity by studying the dynamics between food production and agriculture. He estimated future population numbers by using past food productions numbers, which were similar to those estimated by FAO. According to Hopfenberg, Malthus and Darwin understood that in the absence of limitations of resources – such space and food – populations will grow exponentially. If resources are limited, the growth rate will begin to decline as the population reaches the maximum that the environment can support. Population will continue to decline until equilibrium is reached.

Although Hopfenberg and Quinn's hypotheses have strong biological foundations, they do not seem to maintain when confronted with cases such as Africa, where population sizes have continued to increase despite declining food production on the continent as expected by the Malthusian model. Currently, African nations such as Liberia (4.1 percent), Nigeria (3.49 percent) and Uganda (3.24 percent) have among the highest population growth rates in the world (World Bank, 2009). Nevertheless, grain production has declined 12 percent in the last two decades (Dyson, 1999).

Agriculture Production Indicators

Increases in land dedicated to agricultural purpose also affect a country's agriculture production, particularly in Latin America. The total amount of land used to grow crops in Latin America has increased by 11 percent since 1970, which represents the largest increase of croplands in the world (Gonzalez1985).

Land availability is a determinant factor for agriculture production. According to David Pimentel and Henry Kendall (1994), only a third of the Earth's soil is suitable for agriculture. A 30% of this arable soil is expected to experience erosion by 2050 due to unsustainable agricultural practices. Although the area of arable land is expected to increase by 500 million hectares by 2050, the agricultural productivity of this land will be below current levels (Kendall and Pimentel, 1994). Gilland (2002) argues that to feed today's population with a basic 2900 kcal diet, the average annual rate of cereal production per capita needs to be around 420 kg per year. However, the expected cereal production for 2050 is 360 kg; a 60 kg deficit under a "business as usual" scenario (Gilland, 2002).

Boongarts (1996) proposes that less developed nations could meet 2050 demand if new economic and technological policies enacted to support sustainable agriculture, but not under the current agriculture production model. Agriculture has three main variables that need to be studied: production, population and distribution (Baker, 1977). Since population and production are long term problems, distribution problems should be addressed immediately.

Trade has become a controversial response to solve distribution problems. Scholars argue that trade allows regions with agricultural surpluses to transfer their excess food to regions with agriculture deficits, thus bringing an equilibrium to global production. Currently, six countries –United States, Argentina and France- supply 90 % of global grain exports to numerous countries including Algeria and Nigeria that endure agriculture shortages and declining domestic supply. (Springer and Pingali,2003). Kellogs et al. (1996) argues that agriculture exports decrease a country's ability to be self-sufficient in meeting their food needs. Developed countries have high levels of food exports, while less developed countries import most of their food supply.

Scholars also argue that democratization and political regimes play an important role in a country's agricultural output. Lio and Liu (2008) found that political outcomes which influence agrarian production are result of bargaining between a state's different interest groups. Their results showed that greater democracy is associated with lower agricultural efficiency, which implies that an interest group is taking control over agricultural process (Lio and Liu, 2008).

The consensus among scholars suggests that economic growth directly affects agriculture production. Jenkins and Scalan (2001) argue that an increase in economic growth—measured as increases in GDP—has a positive relationship with the daily intake of calories of children in developing countries. This suggests that development structures and economic policies affect food supply more than increases in agricultural production.

Theory and Hypothesis

Neo- Malthusians have negative expectations concerning agriculture production, since they consider agriculture a land-restricted and economic-oriented process. Population has the potential to outstrip agricultural production. McDonald (1989) argues that regions with higher population will present a negative relationship with agriculture production. Developing regions will present higher population growth rates and lower agriculture production growth rates and developed nations will present an inverse relationship (Pimentel, 1994).

H1: An increase in population growth will decrease agriculture production.

Neo-Malthusians predict a difference between developing regions: Africa, Asia and Latin America; and developed regions: Europe, North America and Oceania. Recent trends show that since 1990, agricultural output has declined in Oceania, Europe and North America (Magdoff and Tokar, 2009). On the other hand, Asian regions experienced an increase in their agriculture production, particularly because of increases in use of fertilizers and genetically modified crops. Additionally, Latin America's agriculture production has recovered since 1990 due recent agricultural shifts in Argentina and Brazil (Dyson, 1994: 383)

H2: The effect of population growth on agriculture production varies across regions.

Research Design

Based upon this background, population growth will be a significant determinant of agricultural production. To explain this relationship I use a cross-sectional time-series data from 1981 to 2008. Consistent with literature I incorporate the control variables of GDP per capita as a measure of economic growth (Jenkins and Scalan, 2001), agricultural land (Kendall and Pimentel, 1994), agricultural imports (Kellogs et al., 1996), political stability (Lio and Liu, 2008) and regional distinctions (Dyson, 1999; Harris and Kennedy, 1999). The population of interest is countries-years, classified by the following UN continental regions: Africa, Asia, Europe, Latin America, North America and Oceania. The study looks at 195 countries during the past twenty-six years using an ordinary least square regression (OLS), meeting the required assumptions. First, the independent variables and control variables are non-random selected. Secondly, I assume that the independent variables and control variables are linearly independent. To avoid multi-collinearity among of control variables, the continental region of Oceania was dropped. Third, I assume normality and no correlation for all variables.

The baseline model examines the relationship between agriculture production growth and population growth, taking in consideration GDP per capita, agriculture material imports, agricultural land and the political stability as control variables. It also incorporates dummy variables for regional classification. The second model uses all the variables, excluding regional classifications. The third model drops the Polity score variable from the regression. Finally, the fourth model analyzes population growth and regional classification.

The primary regression model used for this study is:

Agi. Growth = a + ß1Pop.growth+ ß2GDPPC+ ß3Raw exp. Growth +ß4Agri.Land+ ß5Polity+ ß6Asia + ß7Africa+

ß8Europe+ ß9 Latin America + ß10North America + e

The secondary regression model is:

Agi. Growth = a + ß1Pop.growth+ ß2GDPPC+ ß3Raw exp. Growth +ß4Agri.Land+ ß5Polity+ e

The tertiary regression model is:

Agi. Growth = a + ß1Pop.growth+ ß2GDPPC+ ß3Raw exp. Growth +ß4Agri.Land+ ß5Asia + ß6Africa+ ß7Europe+ ß8Latin America + ß9North America + e

The final regression model is:

Agi. Growth = a + ß1Pop.growth+ ß2Asia + ß3 Africa+ ß4Europe+ ß5 Latin America + ß6 North America+ e

Agriculture Production

The dependent variable is agriculture production growth measured as the Agriculture, value added (annual% growth). It refers to the net output by means of cultivation of crops and livestock production. This number was obtained from the World Development Indicators and measures the annual change of agriculture production vs. the production from previous years.

Population Growth

The primary independent variable is population growth (annual %). It is based on the de facto definition of population, which includes all the residents regardless of legal status or citizenship. The World Bank estimates from various sources including census report and data from the UN Population Division (UN DATA, 2009).

Control Variables

I use GDP per capita, raw agriculture materials imports (%annual change), agricultural land and POLITY score as my control variables. GDP per capita changes measures the economic development –an approximation of the value of goods produced per person-in all the countries included in the model. Agricultural land –measured in sq. miles- refers to the share of land area that is arable, under permanent crops, and under permanent pastures (UN DATA, 2009). Since countries might be importing primary vegetation instead of harvesting it, raw materials imports –Agricultural raw materials imports (% if merchandise) – will reflect the effect of trade on agriculture production. This number was computed using the World Development Indicators dataset. Finally, the POLITY score captures the degree of democracy in a country. I also introduced dummy variables to determine the regional classification -Africa, Asia, Europe, Latin America, North America and Oceania- for each country. For this study, I used the United Nations Statistical Department's Macro Continental Regional classification. During the regression analysis, one of the variables was dropped, which leaves five regions: Africa, Asia, Europe, Latin America and North America (UN Stats, 2010).

Results and Analysis

Table 1 includes the summary of the regression for the all models. Model 1 shows the coefficient estimates on agriculture production growth in all regions, including all the control variables: GDP per capita, Agriculture Raw Materials, Agricultural Land and Polity. The adjusted R^2 for most models is 0.02, which indicates that the study does not account for most of the variation of Agriculture Production Growth, but that population growth explains 0.1 of the variation. In most of the models, the relation between agriculture production and population growth is positive and statistically significant ($p<0.001$). As well, all of the models show significant coefficients for Agricultural Land (*AgriLand*).

The results of Model 1 do not support the hypothesis that population growth negatively affects agriculture production growth or that regional classification plays a role. The coefficient for population growth is positive, which indicates that an increase of one unit in population growth will increase agriculture production growth by 0.60 units. Model 1 also shows that agriculture land has a significant impact on agriculture production. The results indicate that holding all control variables constant, agricultural land will increase agricultural production by 19.2%.

Model 2 does not include coefficient estimates for any of the continental regions. The model does not support the hypothesis that population growth will have a negative effect on agriculture production growth. The coefficient for population growth is positive and significant at the $p<0.001$ level. The results indicate that population growth will increase agriculture production growth by 61.1%. Model 2 also shows that an increase in agricultural land will increase agriculture production growth by 20.9% ($p<0.01$). Furthermore, the results indicate that an increase in democratization will decrease agriculture production growth by 5.8% ($p<0.05$), which could be a result of not including regional classification. Interestingly, Lio and Liu (2008) found the same result in their coefficient estimates for agriculture production and democratization.

Table 1: *OLS regression on Agriculture Production and Population Growth*

Variables	(1)	(2)	(3)	(4)
Population Growth	0.604***	0.611***	0.689***	0.491
	(0.173)	(0.168)	(0.155)	(1.087)
GDPPC(log)	-0.115	-0.709	-0.093	

(0.153)

(0.135)

(0.138)

Raw Imports

0.057

0.077

-0.006

(0.119)

(0.117)

(0.102)

AgriLand(log)

0.192*

0.209**

0.240***

(0.090)

(0.866)

(0.066)

Polity

-0.063

(0.034)

-0.0582*

(0.029)

Africa

-0.420

-0.023

18.149***

(1.040)

(0.682)

(5.618)

Asia

0.438

(0.987)

0.838

(0.662)

18.303***

(5.618)

Europe

-0.062

(0.957)

-0.020

(0.656)

17.252**

(5.705)

Latin America

0.225

(0.985)

0.076

(0.656)

17.656**

(5.655)

North America

0.747

0.306

18.528

(1.46)

(1.380)

(12.792)

Constant

0.289

-0.260

-0.800

-16.308***

(2.154)

(1.628)

(1.638)

(5.056)

N

2157

2115

2778

4042

Adjusted R^2

0.012

0.016

0.02

0.002

Notes: OLS completed in STATA 11 Standard errors in parentheses. Significance: **p*<0.05; ***p*<0.01; ****p*<0.001.

Model 3 does not include coefficient estimates for Polity. Results were similar to those obtained in Model 1. Significant coefficients were attained for Population Growth and Agricultural Land. The results do not support the hypothesis that population growth decreases agricultural production or that the effect differs among regions. The model indicates that population growth will increase agriculture production growth by 68.9% ($p< 0.001$). The results also indicate that agricultural land will increase agricultural production growth by 22% ($p<0.001$). Finally, Model 4 includes coefficient estimates for population growth and regional classification. Surprisingly, the results indicate no significant coefficient for population growth, which does not support the main hypothesis. It is not possible to determine whether the model supports the hypothesis that agriculture production varies among regions. Asia and Africa presented significant coefficients of 18 ($p<0.001$). This means that agriculture production growth will increase 18% more in Africa or Asia, whereas in Europe and Latin America, agriculture production will increase 17%. However, the difference between the coefficients is not as significant as expected. The coefficient for North America was not significant, as result of the limited numbers of cases for this region (N=47).

Conclusion

Scholars have long questioned what factors are important in determining a country's agricultural production capacity. Neo-Malthusian scholars argue that population growth is a primary determinant (Malthus, 1809), while more recent scholars argue that political and economic policies play a more important role in determining production (Jenkins and Scalan, 2001; Lio and Liu, 2008). This paper sought to determine whether population growth affects agriculture production growth. Neo-Malthusians believe that an increase in population will result in decreasing agriculture production, consequently limiting a country's ability to provide food for its citizens. I used OLS regression to evaluate this hypothesis. The results of the models did not support the hypothesis. Indeed, the results indicated a positive relationship between agriculture production and population growth, contrary to the expected by the neo-Malthusian model.

The comparison of population growth and agricultural production changes across regions also did not yield the expected results. Further research needs to be done to determine whether regional location plays a significant role in a country's agriculture production.

The area of land dedicated to agriculture plays a central role in determining a country's agriculture production. However, if population growth rates continue, increasing urbanization will potentially threaten for agricultural production. Further research needs to focus on studying the relationship between population density, land conversion rates and agriculture production.

Undoubtedly, technology will be an important factor in determining agriculture production. Future research needs to study whether nations with lower agriculture production rates should invest in better technology to increase their ability to produce food (Boongarts, 1996). Doubling current crop production to avoid the Malthusian catastrophe—necessary to feed the projected 9 billion global population in 2050—will only be possible if global cooperation is increased to promote more sustainable agricultural practices.

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