Distribution Dynamics of Dietary Energy Supply in the World

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Abstract

This paper investigates the law of motion for the cross section distribution of dietary [illegible] *cal results, persistence in caloric intakes dominates in the short-run. With time, however, upwards mobility gains momentum and the world is moving towards a long-run distribution, which is strongly skewed to the left. The estimated expected first passage times from extreme under-supply to higher intake levels are consistent with speculations that most of the developing countries will attain the 3000 kcal per person per day level by the year 2030.*

Keywords: *caloric intakes, mobility, World*

JEL Classification: C10, D12

Introduction

During the last forty years a nutritional transition has been going on throughout the world, something that is reflected in the dramatic changes in the overall dietary energy supply (DES). In the early 1960s many developed countries were already approaching or even exceeding energy supply levels of around 3000 Kcal/person/day, while the entire developing world- with exception of Argentina, Uruguay, and a few counties in the Middle East and the South Pacific- was suffering from calorie deficits, chronic undernourishment and, in certain cases, outright famine. Since then, the rapid improvement in agricultural productivity brought about by the combination of modern varieties, expansion of irrigation, and widespread mechanization of production made more food available to consumers in developing countries. The average level of DES in the developing world has risen from about 1950 to 2680 Kcal/person/day, and the prevalence of undernutrition has declined from 37 percent in 1970 to 17 percent in 2000 (FAO, 2003a; Bruinsma, 2003; Smil, 2000).

At a global level, the comparison of today's average per capita energy availability with the one in the 1960s reveals a strong trend towards higher DES levels. At a regional level, however, the developments are far from uniform. Dietary energy supply moved swiftly though much of the East Asia, the Near East/North Africa, and Latin America, while sub-Saharan Africa continued to be grossly undersupplied. Moreover, in the 1990s signals of setbacks in the war against hunger appeared making, thus, future prospects to look bleak. In particular, according to the latest estimates (FAO, 2003a)

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from 1995-1997 to 1999-2001 the number of undernourished increased by 18 million. Worldwide, there are 842 million people suffering from under-nutrition including 10 million in the developed countries, 34 million in countries in transition (Common wealth of Independent States/CIS), and 798 million in developing countries. The developments in the 1990s suggest that the goal of reducing the number of undernourished people by half until 2015, set in the World Food Summit (Rome 1996) is unlikely to be achieved. At the same time, there has been an unexpected steady further increase in caloric intakes in certain developed countries (e.g. in the USA it has reached 3800 Kcal), when presumably the largest share of supplies above 3000 Kcal is wasted (Schmidhuber, 2003).

Chronic food insecurity resulting from long-term inadequate energy supply, increases morbidity and mortality (especially among children) and saps the energy of large elements of the population. While caused by poverty, under-nutrition perpetuates a generational cycle of poverty; undernourished children are likely to be intellectually impaired, with diminished productive and creative capabilities. In addition, undernourishment poses heavy future economic burdens to the society as full-term low-birthweight babies are likely as adults to develop chronic illnesses as heart disease, diabetes and hypertension (Bekele, 1998). Under-nutrition is one facet of malnutrition. The other is over-nutrition associated with a sedentary life-style and the continuous availability of food in more affluent counties. Dietary excess and nutrient imbalance problems are considered to be among the few risk factors which account for a significant proportion of deaths and chronic disease in developed countries (The World Health Report, 2002; CINDI Dietary Guide, 2000). It is not accidental, therefore, that changes in dietary energy supplies attract considerable policy attention.

Based on experiences accumulated through a forty year nutritional transition Bruinsma (2003) and Schmidhuber (2003) speculated on future changes in food availability and the likely DES level in 2030. For them, the world population will be increasingly well-fed; most countries will reach the very high caloric supply brackets of the developed countries today; on the average, consumers in developing countries will have nearly 3000 Kcal/day at their disposal; only 6 percent of the developing countries population will be chronically undernourished, and the hunger problem will be largely confined to sub-Saharan Africa; over-nutrition will become a growing problem and disparities in energy supplies will exist between urban and rural areas within the same country.

From the above it is obvious that Bruinsma (2003) and Schmidhuber (2003) suggest that in the next thirty years food consumption patterns and food availability worldwide will converge (with possible exception the counties of sub- Saharan Africa). The objective of the present work is to examine empirically the validity of the speculations that the DES in most developing countries will catch up with the high calorie-intake ones. This will be pursued using the distribution approach developed by Quah (1993a, 1996a and 1996b) and panel data on dietary energy supply from 152 countries during 1961 to 2001. In what follows, Section 2 presents the analytical framework and Section 3 the data; Section 4 presents the empirical results, while Section 5 offers conclusions.

The Analytical Framework

The study of trends in food consumption patterns is not new. Blandford (1984) analyzed the caloric intakes and the national similarities in dietary structure for 21 OECD countries over the period 1960-80. He concluded that dietary energy supplies in most cases had either reached or were rapidly reaching a plateau, although the level of this plateau may differ among countries. Gil, Gracia, and Perez Y Perez (1995), relied on the notions of *beta*- and *sigma*- convergence to assess the dynamic evolution of consumption patterns in 16 EEC countries over the period 1970-90.[1] They found no evidence of convergence in total calorie-intake per capita (although it appeared that there was convergence in calorie-intakes from certain commodities such as milk, eggs, and vegetables). Herrmann and Roder (1995), utilized a variant of the approach by Barro and Sala i Martin (1991 and 1992) to examine empirically converge of food consumption patterns in 22 OECD countries over the period 1978-88. They found strong evidence of convergence in total calorie-intakes per capita but they obtained mixed results with regard to intakes from individual food commodities.

The above studies had a limited focus in the sense that they considered developed countries only. Moreover, the usefulness of Barro's regressions in assessing convergence has been seriously questioned by Quah (1993b and 1996a and 1996b) who showed that a given cross-section distribution - replicating itself over time- is perfectly consistent with arbitrary signs of the projection of the growth rate on an initial level. Given that Barro's regressions are uninformative with regard to convergence or divergence, Quah (1993a, 1996a and 1996b) proposed an alternative approach which involves using discrete Markov chains to estimate a probability model of transitions (that means, the law of motion for the entire cross-section distribution). The key elements of the alternative approach follow.

Let us denote the variable/stochastic process of interest by α and its cross-section distribution at time t by F_t. Associated with F_t is a probability measure λ_t, where $\forall\, y \in R : \lambda_t((-\infty, y)) = F_t(y)$. A simple model for the evolution of F_t or equivalently of λ_t is an autoregression in measures such that for every measurable set A it is the case that

$$\lambda_{t+1} = \int M(a, A)\, d\lambda_t(a) \qquad (1)$$

In (1), M is a *transition kernel* (transition density function) mapping λ_t into λ_{t+1} and trucking, thus, where in F_{t+1} points in F_t end-up (Quah, 1996b). Equation (1) is analogous to a standard time series first-order autoregression, except that its values are distributions rather than scalars or vectors of numbers. The transition kernel encodes information on intra-distribution dynamics (mobility or churning-like behavior, where individual countries transit from one part of the cross-section distribution to another). Rewriting (1) as a convolution

$$\lambda_{t+1} = M * \lambda_t \qquad (2)$$

and iterating yields a predictor for cross-section distributions

$$\lambda_{t+s} = (M * M * ..... * M) * \lambda_t = M^s \lambda_t \qquad (3);$$

taking (3) to the limit as $s \to \infty$ one can characterize the likely long-run or *ergodic distribution* of the stochastic process α. The transition kernel is usually estimated by taking discretizations of the probability measure λ_t, converting, thus, M into a *transition probability matrix*.

The distribution approach provides information on *persistence* and *mobility*, switches in ranks between countries and distances traversed when such switches happen, and on convergence club dynamics (where sub-groups with member countries converge towards each other and diverge away from different clubs). It has been employed by Quah (1993a, 1993b,1996a and 1996b) to analyze converge of per capita incomes at a global and a regional level, by Cameron and Proudman (1998), Bartelsman and Dhrymes (1998), and Fousekis (2004), to the study distribution dynamics of productivity, in the UK manufacturing, the US high tech manufacturing, and the US food and kindred products industry, respectively.

The Data

The data for the empirical application have been obtained by the FAOSTAT (FAO, 2003b). The FAOSTAT database includes information on caloric intakes from almost 180 countries. However, the series are not always complete. A special problem exists with recently established countries which came out of the former USSR, Yugoslavia, and Czechoslovakia. To overcome this problem and to obtain series comparable to those prior to 1991, we aggregated the individual country series using population shares as weights. After aggregating and eliminating countries with incomplete information we have left with a cross-section of 152 observations for the period 1961-2001.

Figure 1 presents certain location and shape characteristics of the calorie-intake distribution over time. The mean and the median of the distribution exhibit clear upward

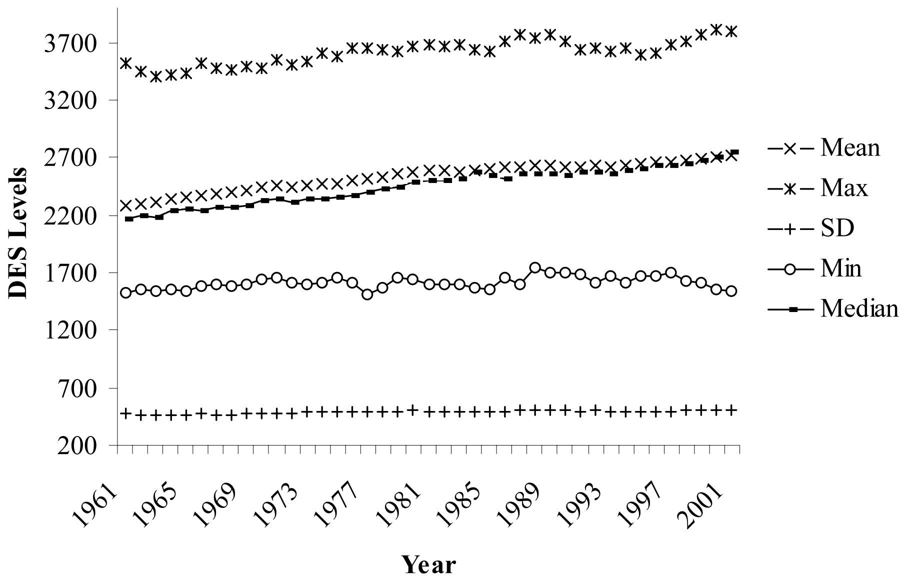

Figure 1. Location and Shape Characteristics of the Evolving DES Distribution

trends. The mean in all years but 2001was above the median, suggesting an asymmetry of the cross-section distribution (elongated left tail). The asymmetry, however, was getting less pronounced with time. The maximum value appears to increase as well but at a lower pace, suggesting that the countries with the highest intakes have been approaching the upper asymptotes (maximum potential intake levels). The minimum value exhibited an upward trend until the late 1980s, and a downward trend in the most recent years. As mentioned above, the reduction of the cross-section standard deviation over time has been often interpreted in the relevant literature as an indication of *sigma*-convergence. Quah (1996a), however, argued that this is not necessarily the case since a reduction in standard deviation does not preclude a move towards a twin- or multi-peakedness (that is, polarization/stratification and club formation). Here, the standard deviation exhibits a moderate upward trend (from around 470 in the 1960s, it reached 495 in the 1990s).

Table 1 presents the countries, which occupied the bottom and the top of the cross-section distribution of DES in 1961, 1971, 1981, 1991, and 2001. In 1961, the bottom ten included countries from all continents but Europe. As the nutrition transition gathered momentum, however, countries in North Africa, Neat East, East Asia, and Central America showed an upward mobility. In the last two decades, the bottom of the distribution has been primarily occupied by countries in Africa (and, in particular, of the subSaharan Africa). It is noteworthy that Libya which in 1961 had the seventh lowest intake ended up in 1981 with the fifth highest one. Countries such as Portugal and Greece with intakes at or below the 2500 Kcal mark in the 1960s have advanced to the top five in 2001. France belonged to the group of the top ten in all selected years and the same is true for Italy in 1971, 1981, 1991, and 2001, and for Ireland in 1981, 1991, and 2001. At the same time, a number of former socialist countries such as Poland, Yugoslavia, and Bulgaria disappeared from the group of top ten in the 1990s. Overall, the causal examination of Table 1 suggests that there have been countries which tended to retain their position in the cross-section distribution along with countries which showed a considerable upward or downward mobility.

The Empirical Results

Transition probability matrices with five states (0: lowest intake; 1: lower middle intake; 2: middle intake; 3: upper middle; and 4: highest intake) have been estimated using the TSRF econometric package (Quah, 2000). Table 2 presents the one-step (one-year) transition probability matrix for 1961-2001. The upper limits for each state have been determined by dividing the space of possible values of caloric intakes into discrete cells such that there is a roughly equal number of country/year observations in each cell.[2] The numbers in parentheses in the first column of Table 2 are the country/year observations beginning in a particular state, while the numbers in the brackets in the first row give the range of intakes for each state. For example, 1201 observations begun in state 1(lower middle), the upper and the lower limits of which are 2303 and 2094, respectively. The remaining rows and columns present the one-step transition probabilities. As known, the one-step transition probability is defined as

Table 1. Countries at the Bottom, and the at Top of the DES Distribution (selected years)

1961		1971		1981	
Bottom Ten	**Top Ten**	**Bottom Ten**	**Top Ten**	**Bottom Ten**	**Top Ten**
Malvides*	Austria	Tanzania*	France	Burkina Faso*	Czechoslovakia
Burkina Faso	Bulgaria	Malvides	N. Caledonia	Chad	France
Djibouti	France	Burkina Faso	USSR	Mali	Iceland
China	UK	Cape Verde	Hungary	Ghana	Hungary
Niger	Iceland	Yemen	Czechoslovakia	Cambodia	Libya
Papua New Guinea	Finland	Djibouti	Italy	Djibouti	Switzerland
Libya	Poland	Phillipines	Switzerland	Comoros	Italy
S. Arabia	Czechoslovakia	Nepal	Poland	Mozambique	Ireland
Saint Kitts and Nevis	Ireland	Algeria	Yugoslavia	Gambia	Bulgaria
Tanzania	Switzerland**	Mali	Bulgaria**	Banglandesh**	Yugoslavia**

1991		2001	
Bottom Ten	**Top Ten**	**Bottom Ten**	**Top Ten**
Mozambique*	Yugoslavia	Kongo*	Hungary
Angola	Turkey	Burundi	Germany
Haiti	USA	Comoros	France
Chad	Hungary	Zambia	Ireland
Central African Republic	Austria	Sierra Leone	Italy
Cambodia	Greece	Liberia	Belgium
Burundi	France	Central African Republic	Portugal
Djibouti	Belgium	Angola	Greece
Niger	Ireland	Cambodia	USA
Comoros	Italy**	Mongolia	Austria**

* (**) indicates the lowest (highest) intake per capita

$$P_{i,j}^{(t,t+1)} = \text{prob}(a_{t+1} \in j / a_t \in i) \tag{4}$$

and stands for the probability that in period $t+1$ the stochastic process a will be in state j, given that it was in state in i one unit of time earlier. Here, a is the caloric per capita intake and $i, j = 0, 1, 2, 3, 4$.

Table 2. The One-Step Transition Probability Matrix

States	0 [1511-2094]	1 (2094-2303]	2 (2303-2614]	3 (2614-3050]	4 (3050-3837]
0 (1199)	0.87	0.13	0	0	0
1 (1201)	0.09	0.75	0.15	0	0
2 (1179)	0	0.11	0.81	0.09	0
3 (1172)	0	0	0.05	0.87	0.08
4 (1177)	0	0	0	0.06	0.94

The elements in the main diagonal provide information about mobility (or persistence). According to the results, 94 percent of countries in state 4 in any given year will end up in the same state in the immediately following year. For states 0 and 3 the relevant figure is 0.87, while for states 2 and 1 the figures are somehow lower (0.75 and 0.81 respectively). We conclude therefore, that in one year persistence has been very strong for the highest intake countries, while mobility has been relatively easier for the lower middle and the middle intake ones. The off-diagonal elements provide information on the type of mobility (upwards or downwards). For example, the probability that a country in state 2 will transit in state 3 is 0.09 and the probability that it will transit to state 1 is 0.11. The elements above the main diagonal are always higher than their symmetric below the main diagonal suggesting that for all states of the stochastic process upwards mobility has outweighed downwards mobility. Indeed, the sum of elements above the main diagonal (reflecting upwards mobility from all states) is 0.45, while the sum of elements below the main diagonal (overall downwards mobility) is only 0.31. The prevalence of upwards mobility should be attributed to the improvements in agricultural productivity which during the last 40 years has increased food availability worldwide.

The k -step transition probability is defined as

$$P_{i,j}^{(t,t+k)} = prob(a_{t+k} \in j / a_t \in i) \quad (5)$$

and stands for the probability that in period $t+k$ the stochastic process a will be in state j, given that k units of time earlier it was in state in i. The one-step transition probability matrix has been iterated a number of times equal to the effective sample to obtain the corresponding 39-step matrix. Table 3 presents the results. As expected, mobility is much more higher in a longer-run. This is especially true for states 0 to 3. Still, however, 43 percent of countries which begun in state 4 will not transit out of that state even after 40 years suggesting that, once attained, high (above 3000 Kcal) levels will not be easily reduced. In contrast with the very short-run where the states communicate only with the adjacent ones, in the longer-run all states communicate with each other.[3] However, there is a considerable degree of asymmetry in the communication. For example, only 13 percent of the countries that begun in state 4 will transit to state 1 or 0, while 44 percent of countries that begun in state 0 will transit to states 3 or 4.

Table 3. The Thirty Nine-Step Transition Probability Matrix

States	**0** [1511-2094]	**1** (2094-2303]	**2** (2303-2614]	**3** (2614-3050]	**4** (3050-3837]
0 (1199)	0.16	0.18	0.21	0.23	0.21
1 (1201)	0.14	0.16	0.20	0.25	0.25
2 (1179)	0.11	0.14	0.18	0.27	0.30
3 (1172)	0.07	0.10	0.15	0.29	0.39
4 (1177)	0.05	0.08	0.13	0.30	0.43

The ergodic distribution is unconditional in the sense that it gives the probability that a country will occupy a given state in the long-run, independently of the state it belonged initially. Table 4 presents the egrodic distribution. It appears that this distribution is strongly skewed to the left, with 64 percent of countries occupying the upper middle or the highest intake states and with 19 percent occupying the lower-middle or the lowest intake states. According to the results, therefore, the world is moving towards a distribution where more than 60 percent of the countries will have intakes well above the "recommended" levels, while 10 percent or more will be severely undersupplied.[4] In any case, the difference in intake levels in the two tails of the cross-section distribution will be quite large (close to 1800 Kcals).

The transition matrices provide interesting information about the probabilities of transition. Of equal importance, however, is the knowledge of the time required for these transitions. To investigate it we use here notion of the *first passage time* (Narayan Bhat, 1972). Let $f_{ij}^{(n)}$ be the probability that the first visit of the process to state j when it begun from state i will take place in n steps. Formally,

$$f_{ij}^{(n)} = prob(a_n \in j; a_r \notin r\, (r = 1, 2, ..., n-1) / a_0 \in i) \quad (6).$$

The expected value of the first passage time is then

$$F_{ij}^{(n)} = \sum_{n=1}^{\infty} n f_{ij}^{(n)} \quad (7).$$

Table 5 presents the expected first passage times from extreme under-supply (1600 Kcal) to 2600 Kcal (the average for the developing world) and to 3000 Kcal (which characterizes the developed nations). It appears that it will take 19 years, on the average, for a country currently in extreme under-supply to reach the 2600 Kcal mark, and 42 years, on the average, to reach the 3000 Kcal mark. The difference between the expected passage first times from 2600 Kcal and 3000 Kcal is 23 years, suggesting that our results are consistent with the speculations by Bruinsma (2003) and Schmidhuber (2003) that by year 2030 most of the countries in the developing world are likely to attain intakes of 3000 Kcal.

Table 4. The Ergodic Distribution

States	0	1	2	3	4
Probabilities	0.08	0.11	0.16	0.28	0.36

Table 5. Expected First Passage Times

	Subsequent Level		
Initial Level	2200	2600	3000
1600	7.4	18.8	42.4

Conclusions

The objective of the present paper has been to investigate the law of motion for the cross-section distribution of dietary energy supply in the world. This has been pursued using the distribution approach and a panel of 152 countries for the period 1961-2001. According to the empirical results:

1) Persistence in per capita caloric intakes is very high in the short-run at the top and the bottom of the distribution. In the longer-run, mobility is getting higher especially for the low-intake countries.

2) Upwards mobility outweighs downward mobility, reflecting the increase in food availability worldwide. As a result, the world appears to be moving towards a long-run distribution of intakes which is strongly skewed to the left with 64 percent of countries occupying the top part of the distribution (intakes above 3050 Kcal), and 19 percent occupying the bottom part (intakes below 2303 Kcal). Despite the dominance of upwards mobility, the differences in intakes between the two extremes of the distribution will remain quite large (close to 1800 Kcals), implying that convergence is not very likely.

3) The speculations that most of the developing countries will have nearly 3000 Kcal/person/day at their disposal by year 2030 appear to be valid. Indeed, the expected first passage time from 3000 Kcal for a country that begins with 2600 Kcal is found to be 23 years.

As mentioned in the introduction over-nutrition and under-nutrition are the two facets of malnutrition both taking their toll in terms of human lives and imposing economic burdens to societies not only in the present but in the future as well. Given that a large share of supplies above 3000 Kcal are probably wasted, certain countries at the top of the distribution should lower their intakes something that can be achieved through information regarding the adverse health effects of nutrient excess and imbalance. For the calorie-deficient countries (which are at the same time the low-income ones), the long-run solution lies in improving the poors' access to income-earning opportunities or assets which, in turn, will vest them with a socially recognized claim on the available food supply.

Notes

[1] *Beta*-convergence occurs when consumption in lower calorie-intake countries grows faster than in higher calorie-intake ones. It can be assessed by the negative sign of the coefficient of the cross-section regression of the growth rate of calorie-intakes on an initial intake level (the so-called Barro's regression). *Sigma*-convergence is defined as a reduction in the cross-section standard deviation over time. Barro and Sala i Martin (1991 and 1992) argued that *Beta*-convergence is a necessary but not sufficient condition for *Sigma*-convergence.

[2] The observed differences, which are always lower than the number of years in the sample, are exclusively due to rounding errors. The transition model is forward-looking and the sample endpoint must be reduced by one. By contrast, the autoregression model is backward-looking and the sample beginpoint must be raised by one. Therefore, the effective sample for the period 1961-2001 is 1962-2000.

[3] We say that states i and j with $i \neq j$ communicate when i can be reached from j (and vice versa) in a finite number of steps.

[4] The "recommended" level depends on the gender, the age, and the physical activity of a person. It is generally, accepted, however, that for an "average" person an intake level of around 2550 can meet the energy needs (Leathers, 2003; Variyam, 2002).

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