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Does global meat consumption follow an environmental Kuznets curve?

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In this article, we use data on meat consumption, per capita income, and other socioeconomic variables for 150 countries to determine whether data support the hypothesis that per capita meat consumption follows a Kuznets-style inverted U-curve. In other words, as nations increase their real per capita incomes, while individuals at first consume more meat, ultimately, over time and with increased income, do they moderate their consumption? Our results signal that although there is evidence of a Kuznets relationship, the income at which our data suggests a deceleration of meat is large enough that for many countries this deceleration will not be reached in the foreseeable future. In a cross-section sample of low-income countries, we find no evidence of a Kuznets relationship. In a cross-section sample of high-income countries, we do find a potential Kuznets relationship and a deceleration of meat consumption at a per capita income of US$49,848. In the full panel-data sample combining high- and low-income countries, including data on land area and urbanization, our results suggest an inflection point in meat consumption at an income of US$36,375, still quite high for any realistic impact. Thus, our results highlight that effectively decelerating the global demand for meat may require aggressive and potentially controversial policy interventions, which, while leaving individuals with less choice, would address the otherwise devastating environmental impacts of increasing meat consumption.

KEYWORDS: income, socioeconomic aspects, environmental impact, meat production, food consumption

Introduction

Approximately three billion people are currently chronically malnourished while our agricultural systems are concurrently degrading land, water, and biodiversity, and altering climate on a global scale (WHO 2000; Foley et al. 2011). Despite malnourishment at the individual level, overall, increasing population and consumption are placing unprecedented demands on agriculture and natural resources (Pelletier & Tyedmers, 2010). Meat, the most unsustainable form of food that humans husband and consume in particular places a heavy strain on global resources. Factory-based farming has overtaken transportation as the largest contributor to global climate change, and the impacts on water, air, and soil are without parallel. In many developing countries, these natural resources are already compromised, turning the increased consumption of meat into a potential environmental disaster. It is clear, forecasting into the future, that global population growth will further stress global resources.

In this article, we emphasize another source of increasing demand for meat: per capita income growth, most significantly in developing countries such as China and India. We further investigate whether data from higher income countries reveals a projected deceleration of meat demand once a threshold income is reached. This deceleration could offer some hope of a natural moderation to an otherwise serious growth pattern in demand. The modeling of this pattern of deceleration takes on the potential form of a Kuznets curve.

In his seminal paper from 1955, economist Simon Kuznets first discussed the nonlinear relationship between a country’s stage of development, measured through income, and the income distribution within the country (Kuznets, 1955). According to Kuznets, as a country moves along its path of growth, it first experiences an increase in income inequality as wealth increases; however, later, with changing social preferences and the development of strong institutions empowered to redistribute wealth, income inequality decreases. Thus, graphing a measure of income inequality, for example the Gini coefficient, over time would result in a bell-shaped, quadratic curve showing an ultimate inflection point.¹

¹ The Gini coefficient is used to compare income inequality across countries and can take on values between 0 (perfect equality) to 1
This approach, that certain characteristics of economic growth are nonlinear, has been applied in other areas as well, most significantly in the study of the link between economic growth and pollution. The World Health Organization (WHO) established the Global Environmental Monitoring System (GEMS) and collected data on both water and air pollution to determine whether pollution in a developing country would have a similar inverted U-shape, called an environmental Kuznets curve (EKC). Later, Shafik & Bandyopadhyay (1992) and Grossman & Krueger (1993) both estimated cross-country relationships between income and air and water pollution, deforestation, and waste output. The former study concluded that airborne sulfur dioxide (SO\textsubscript{2}) and smoke concentrations began to diminish after an income level of US$3,000–US$4,000 (in 1992 dollars) per capita was reached, and the latter found the same but with a turning point of US$4,000–US$6,000. Several other research studies have since verified this curve, with inflection points differing only slightly.

Later research focused on the question of how this shape consistently arises in individual countries as they develop. Copeland & Taylor (2003) recapitulate these studies, detailing four possible mechanisms by which EKC emerges: control not being implemented until pollution builds up to a discernible amount; strong increasing returns to scale in pollution abatement; reduced corruption in government enhancing abatement effort; and a natural origin, although the peak could occur at virtually any income level.

More recently, Deacon & Norman (2006) identify a gap in previous research: data had not been analyzed for individual countries, thus these researchers investigated time-series data by country for criteria pollutants including SO\textsubscript{2}, smoke, and particulates to determine what impact development has on in-country environmental quality. Further, Deacon & Norman (2006) assert that EKC-consistent patterns are most likely to emerge if using three points, as then only four shapes are possible: monotone-increasing, monotone-decreasing, single-peaked, and single-troughed. The first three are potentially consistent with the EKC hypothesis and the fourth is EKC-inconsistent. Deacon & Norman (2006) found that many factors complicate the data and that only three of the 25 countries investigated followed this EKC hypothesis.

Several authors have extended the hypothesis of an EKC relationship into the general category of animal welfare and the specific relationship between income and meat consumption. Vinnari et al. (2005) considered the relationship between meat consumption and income in the European Union (EU) and found a potential apex at the per capita income of US$15,000. Using the broader definition of animal welfare, Frank (2008) considers the relationship between income and meat consumption as well as the impact of income on a more general “concern for animal welfare.” Frank considers a sample of high-income countries in his study—focusing on the United States—and his models seem more successful in finding linear relationships. Rather than showing a rigorous Kuznets curve, they provide more background as to why an apex in the relationship between income and meat consumption might exist. For example, Frank finds strong evidence that higher incomes result in better treatment of companion animals, implying a stronger emotional bond with and concern about animals.

Past studies on the Kuznets relationship and the environment highlight the complications of using cross-section versus time-series data to investigate what are supposed to be dynamic relationships. In general, time-series data following one country can be effective in understanding short-run deviations from a long-run process or path while cross-section data can be effective in understanding long-run stable relationships (with the assumption that long-run relationships are robust to the cross-section dimension). In our study, we use both cross-section and panel (time-series) data. Further, to build on the evidence suggested between income and meat consumption (and animal welfare) in high-income countries, we explicitly include developing countries in our data set. The rapidly growing populations and incomes in countries such as China and India, we believe, make understanding a potential Kuznets in such countries especially important. To begin our discussion, we review the environmental impact of meat husbandry and consumption.

**Environmental Impact of Meat Consumption**

Agriculture is a major force driving the environment beyond the boundaries of what the planet can produce (Rockstrom et al. 2009). Of all activities humans engage in on Earth, producing, distributing, and consuming meat has the largest environmental impact on scales ranging from local to global. The industrial, concentrated animal-feeding operation (CAFO) practices of raising animals for food in confined quarters with lax restrictions on resultant pollutants are responsible for unsustainable resource use and significant air pollution and resultant climate change, water overuse and pollution, land degradation, arable soil erosion, fossil-fuel use, climate...
change, and biodiversity loss. Similarly, these environmental problems occur in developing nations, and biodiversity loss is particularly troubling in Earth’s rainforests. To meet the world’s future food security and sustainability needs, food production must grow substantially while, at the same time, agriculture’s environmental footprint must shrink dramatically (Foley et al. 2011).

Air Pollution and Climate Change

Estimates of greenhouse gases (GHG) emitted by CAFOs vary: in its book Livestock’s Long Shadow: Environmental Issues and Options, the Food and Agriculture Organization of the United Nations (FAO) (2006) estimates that the meat industry contributes 18% of all emissions of GHGs, although Koneswaran & Nierenberg (2008) report a 51% minimum of total emissions, which highlights the difficulty in constraining emissions totals. Even the conservative 18% FAO estimate means livestock are responsible for 40% more than all the cars, trucks, planes, trains, and ships in the world combined. In its 2006 report, the United Nations (UN) estimated that 7.8 billion tons/year of carbon dioxide (CO2) are produced in the raising of meat animals. Globally, ruminant livestock (cows) produce about 80 million metric tons of methane annually, accounting for about 28% of global methane (CH4) emissions from human-related activities (USEPA, 2006). This is in addition to the GHG emissions used in producing the crops fed to livestock (Parry et al. 2007; Verge et al. 2007).

Animals raised for human consumption are also responsible for nearly 70% of anthropogenic ammonia emissions, which contribute significantly to acid rain and acidification of terrestrial and aquatic ecosystems. The livestock sector emits 37% of anthropogenic CH4 (with 23 times the global warming potential—or GWP—of CO2)...[and] emits 65% of anthropogenic nitrous oxide (with 296 times the GWP of CO2) (Parry et al. 2007).

Water-Resource Use and Degradation

Seventy percent of global freshwater withdrawals (80–90% of consumptive uses) are devoted to irrigation (Foley et al. 2011). Furthermore, rain-fed agriculture is the world’s largest user of water (Gordon et al. 2005). Livestock production also uses significant amounts of water and generates large volumes of water pollution. Sixty gallons of water are necessary to produce a pound of potatoes, yet a pound of beef requires over 12,000 gallons of water. An estimated 240 trillion gallons per year of water, equal to 7.5 million gallons per second of water, is used for livestock production (UN, 2006). Indeed, the UN states that “water used by the [livestock] sector exceeds 8 percent of the global human water use” (Parry et al. 2007).

Animal agriculture in the United States is responsible for 33% of overall water pollution, including the aquatic pollutants nitrogen and phosphorous, and half of its water pollution from antibiotics. In the United States, 80% of surface-water bodies are polluted due to livestock production, and nearly 17 billion tons per year (over a million pounds per second) of chicken, hog, and cow waste are produced globally. The world’s seven billion human inhabitants produce just 1/60th of this waste. This excrement makes the livestock sector the largest source of water pollution in the world, contributing to overfertilization (eutrophication) of surface waters, which creates, among other things, dead zones in coastal wetland ecosystems, irreversible destruction of tropical coral reefs, and human infectious diseases such as E. coli (UN, 2006). Fertilizer for crops fed to cattle also creates nutrient excess, which are especially large in China, Northern India, the United States, and Western Europe (Vitousek, 2009).

Soil Erosion and Land Degradation

Agriculture occupies about 38% of Earth’s terrestrial surface—the largest use of land on the planet (Ramankutty et al. 2008). Livestock in CAFOs are fed on grain, a highly inefficient method of obtaining calories, and estimates range from a 4:1 up to a 54:1 energy-input to protein-output ratio, meaning, for example, that the United States could feed up to 800 million people with the grain currently fed to livestock. Therefore, producing animal-based food is much less efficient than the harvesting of grains, vegetables, legumes, seeds, and fruits for direct human consumption. Meat consumption thus has staggering economic and environmental repercussions.

The production, distribution, and consumption of meat, dairy, and eggs is responsible for over half of the erosion that causes sedimentation of waterways, or 40 billion tons per year of soil loss (6 tons per year for every human on the planet). Of this outsized volume, 60% accumulates in surface waterways (rivers, streams, and lakes), making these water bodies prone to flooding and contamination from agrochemicals (inorganic fertilizers and petroleum-based pesticides) sorbed to sediment grains (Foley, et al. 2007). Further, lost soil may become windborne, thus increasing the volume of dust in the atmosphere. Finally, FAO (2005) concludes that expanding livestock production is one of the main drivers of the destruction of tropical rain forests in Latin America, which is causing serious environmental degradation globally (Foley et al. 2007; Gibbs et al. 2010). More food can be delivered on less land by changing our dietary preferences. Simply put, we can increase food availability (in
terms of calories, protein, and critical nutrients) by shifting crop production away from livestock feed, bioenergy crops, and other nonfood applications (Foley et al. 2011).

**Fossil-Fuel Use**

Significant amounts of fossil fuels are used in the production, distribution, and consumption (including refrigeration) of meat. In fact, using current factory farming methods, it takes more than ten times as much fossil fuel to make one calorie of animal protein as it does to make one calorie of plant protein. Fossil fuels are nonrenewable, finite resources that are highly polluting, responsible for CH₄, CO₂, mercury, arsenic, and radioactivity found in air and water.

**Land Use and Biodiversity Loss**

Over ten billion acres of the terrestrial portion of Earth is used to raise animals for food. According to *Livestock’s Long Shadow* (2006):

> [L]ivestock production accounts for 70 percent of all agricultural land and 30 percent of the land surface of the planet…70 percent of previous forested land in the Amazon is occupied by pastures, and feed crops cover a large part of the remainder…about 20 percent of the world’s pastures and rangelands, with 73 percent of rangelands in dry areas, have been degraded to some extent, mostly through overgrazing, compaction and erosion created by livestock action.

A total of 836 million tons per year of grain (including corn) is grown to feed livestock. If this grain were used directly for human consumption, the human agricultural impact on the environment would be significantly lessened. Five million acres of Amazon rainforest are obliterated each year, either to graze livestock or to grow grains for their consumption. Over 90% of Amazon deforestation is due to raising animals for food. Over one thousand species go extinct every year due to animal-based agricultural activities.

Further, the FAO (2006) concludes:

> [T]he livestock sector may well be the leading player in the reduction of biodiversity...livestock now account for about 20 percent of the total terrestrial animal biomass, and the 30 percent of the earth's land surface that they now pre-empt was once habitat for wildlife…An analysis of the authoritative World Conservation Union (IUCN) Red List of Threatened Species shows that most of the world's threatened species are suffering habitat loss where livestock are a factor.

As developing nations tend toward both Western-influenced, meat-rich diets and the agricultural techniques involved in procuring meat, the local, regional, and global consequences of this transition are sure to be felt. In short, we need better data and decision-support tools to improve management decisions (Zacks & Kucharik, 2011).

**The Economic Decision to Consume Meat**

For economists, the consumption decision at the household level presumes that the household chooses to spend its income in a manner that maximizes the household’s satisfaction. This decision-making process requires that a household use information on its income, the prices of the goods it considers consuming, and how tradeoffs between consumption goods affect its overall satisfaction to reach the choice to consume an optimal bundle of goods. Within this process, economists define economic goods as having certain properties relative to their own price and overall household income, and income elasticity respectively. Price elasticity measures the responsiveness of consumers, in the consumption decision, to price changes of a given good, and income elasticity measures the responsiveness of consumers, in the consumption decision, to changes in income. In this section, we discuss past empirical studies on the impact of price and income on the decision to consume meat, focusing on studies done in developing countries.

**Price Elasticity of Meat**

Gallet (2010) reviews past studies on meat-price elasticities. In general, Gallet’s summary of previous findings suggests that all meats have inelastic prices. The median value for past studies on meat in general is given as –0.710; the median estimate for beef is reported as –0.869 and pork –0.780. (Unit elasticity occurs when the percentage change in quantity demanded is equal to the percentage change in price, so \( E_d = -1 \), and relative elasticity occurs when the percentage change in quantity demanded is greater than the percentage change in price, so \( E_d < -1 \)).

Price elasticity becomes especially important in the case of a policy interest in moderating meat consumption through a tax; price elasticities are critical in evaluating the financial impact on consumers and producers. To the extent that general growth in demand for meat could in turn increase its price, a negative price elasticity suggests a potential source of moderation in overall meat consumption. For exam-
ple, a November 2011 news story from an online UK financial journal suggested that growth in China’s and India’s demand for meat caused a 25% increase in the price of turkey in the UK (Elliott, 2011).

**Income Elasticity of Meat**

Of more direct interest to this study is the relationship between income and meat consumption. We now investigate past evidence on that relationship. York & Gossard (2003) conducted a cross-national study of per capita meat consumption using economic and ecological variables. The data include 132 countries categorized as being from one of four cultural regions: the West, Africa, Asia, and the Middle East. The authors confirm that income, as measured in their study by per capita gross domestic product (GDP) purchasing power parity (PPP), increases per capita meat consumption by 2.67 kilograms (kgs) for each increase in income of US$1,000. They also find that the percent urbanization of a country’s population has a positive impact on meat consumption as well as land exploited per capita; the latter, they hypothesize, is due to the ecological requirements of animal husbandry. Consistent with a positive income-growth and meat-demand relationship, Gehlar & Coyle (2002) find that the composition of world agricultural trade has substantially changed in the past two decades; for developing countries, consumption and trade are shifting from basic staples toward higher value livestock products.

Other studies estimate income—or expenditures used for consumption and not saving—elasticity. Shono et al. (2000) measure expenditure elasticities for food-consumption products, including meat, using data from urban income groups in China, while Jiang & Davis (2007) estimate elasticities for rural Chinese households. The more aggregated urban data yield estimates for income elasticity for meat that are both positive and relatively inelastic. Jiang & Davis’s estimate for the income elasticity of pork is 0.462 and beef 0.496. The only food products which have estimates larger than one in their study—relatively responsive to changes in income—are fruits and dairy products, which the authors acknowledge are viewed as luxury goods in China. The authors’ overall conclusion about the change of demand for meat in China is that while meat demand is increasing with income, China is likely to follow a path closer to other Asian countries, rather than Western countries, which have higher consumption of seafood. In fact, the authors find the income elasticity of carp (0.856) and shrimp (0.762), the only seafood products in their study, to be higher than meat.³ In their study on rural meat consumption, Jiang & Davis (2007) use household-level data for 1,520 households in Jilin Province. The authors model the household-consumption decision in a first stage as allocating income across food and nonfood consumption, and in a second stage as taking the household-food budget and allocating it across four categories: grains, vegetable products, animal products, and other foods. In the final stage, the household takes the budget for each category and allocates purchasing decisions within the category. Given the household-data available for China, only the decision across animal products can be rigorously estimated for the family. Their estimate for income elasticity for meat is close to the urban estimates at 0.88. Interestingly, correcting for specific household characteristics does not substantively change the estimate, lowering it only to 0.87.

Several other studies estimate household-income elasticity for meat in other developing countries. Hendriks & Lyne (2003) consider data from 99 households in two communities of Kwa-Zulu Natal, South Africa. In their results, both overall food and specific meat elasticities are close to unity: the food elasticity for the community of Sawyimana (46 households in the study) is estimated to be 1.09 and for meat 0.97; for Umzumbe (47 households) the estimates were 0.98 and 1.04 respectively. The authors recognize that preferences for increased meat consumption with increases in income could actually be higher than the estimates suggest, as consumption could be mitigated by the lack of refrigeration for these households. Another study, using data from 9,189 households, estimates income elasticities for meat in Viet Nam as 1.068 for rural households and 0.692 for urban households (Le, 2008). This interesting result on the rural/urban divide contrasts with results from the cross-national study by York & Gossard (2004). When the latter divided the households by income quintiles, they found that the income elasticity of meat increased for the wealthier quintiles, a result which certainly challenges the possibility of a Kuznets curve. The estimated elasticities for quintiles (poor to wealthy) are 0.22, 1.12, 1.86, 2.07, and 2.75. These estimates suggest that mean consumption for the wealthy in Viet Nam is highly elas-

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² The use of “purchasing power parity” and “constant 2005 dollars” allows for two dimensions of the neutralization of price effects across countries and across time to facilitate direct comparison. “Purchasing power parity” adjustments in the data control for different prices across countries, accommodating for the fact, for example, that one could live much better on US$5,000 a year in Botswana than the UK. Using “constant 2005 dollars” converts the data from nominal values to real values, neutralizing the impact of a basic upward trend in prices over time.

³ For comparison purposes, the authors quote earlier results on urban areas in China (Huang & Bouis, 1996), which find overall income elasticity for meat to be closer to one, 0.967, with pork at 0.916, beef and mutton at 0.788, and poultry at 1.222.
tic and responsive to income, and further development in the country would cause great increases in the demand for meat.

The above studies should be seen as representative, not exhaustive, of the estimation of expenditure elasticities. All of the studies reinforce the notion of a positive response to meat demand as income increases in developing countries. However, the magnitude of the increase varies to some degree across the studies. Simply put, all these results acknowledge the first side of the hypothesized Kuznets relationship. A mechanism for an ultimate downturn in meat consumption, if anything, is challenging for these countries. The studies also raise other issues, such as a dominant role for rural versus urban location.

**Background to a Meat Consumption EKC**

In the justification of a Kuznets inverted curve for both income distribution and pollution, an initial burst of industrial activity is ultimately offset by a societal interest in mitigating income inequality and pollution primarily through strong, responsive, and responsible institutions. Changes in meat consumption, which would mitigate an upward trend, would be very different, structurally, from the narrative of a change in social values and desired intervention by strong institutions to either redistribute income or mitigate pollution. Rather, changes in the decision to consume meat depend on an increased awareness of the environment, animal rights, and human health, striking directly at individual consumer preferences and ideas that typically persist about what makes an individual “happy” or “better off.” Further, while the effects of pollution on society may be directly visible—such as smog-filled air or discolored water—the environmental impact of meat may be more abstract to individual consumers, making an argument predicated on social need or economic negative externality more difficult.

To fully follow a Kuznets pattern, the relationship between income and meat consumption must have a turning point, an income level after which the demand for meat decelerates. As is the case with the Kuznets curves described previously, this requires some structural change in the underlying relationship between income and the desire to consume meat. In a study on the social influences of meat consumption in the United States, Gossard & York (2003) discuss factors that may influence consumer demand for meat and cite the rise of vegetarianism in Western societies. Other factors such as the negative health effects of meat consumption, government subsidies for meat-producing industries, and cultural manipulation are all discussed as playing a potential role in American meat consumption. Due to data limitations, however, the authors are only able to model the impact of specific demographic variables—age, gender, race, weight, and region, as well as income, education, and occupation—in their regression analysis of meat consumption for a survey of 15,028 individuals conducted by the United States Department of Agriculture in 1996. Results from their study, which may add to the interpretation of cross-national data, include negative and significant relationships between age and education and meat consumption and the significant finding that women consume less meat than men. Finally, they find that social class influences meat consumption, a claim they substantiate with the finding that workers in professional occupations consume significantly less meat than those in laborer occupations. To the extent that income can capture education levels and class dynamics in the cross-section, and if the dynamics are indeed similar cross-nationally, it would allow potential for the nonlinear relationship we are hoping to find.

As discussed previously, Frank (2008) also finds that as incomes increase (in his set of developed countries) there tends to be more interest in animal welfare and empathy toward companion animals, which could extend to an overall interest in animal rights.

**Data Analysis**

In our study, we use data for 1980–2009 taken from the FAO to compute the per capita consumption of meat. Specifically, we use the data series for food-supply quantity (kilograms per capita) for bovine meat, pig meat, and poultry. Data for per capita GDP (PPP in constant 2005 dollars), the percent urbanization of a country’s population, and the percent of a country’s land area used for agriculture are taken from the World Bank *Indicators of Development* (2013). The measures for land area and urbanization are used to proxy the relative scarcity of agricultural and natural-resource-based land use and resultant relative high cost of animal husbandry within a domestic economy, as well as the socioeconomic phenomenon, dominant in most developing economies, of rural to urban migration.

By using a traditional ln-ln regression specification, using the natural log of meat consumption and natural log of income, we can report a point estimate for income elasticity, which provides an initial comparison of how our data perform with respect to previous studies. Specifically, the estimated slope coefficient in a ln-ln regression model can be interpreted as an elasticity. More importantly, to test our Kuznets hypothesis, we use a polynomial specification for income both to test the statistical significance of the
second-order polynomial and to solve for an estimated turning point for income.\(^4\)

An initial consideration of the data for the last year in the data set, 2009, reveals the following about meat consumption for the 150 countries: approximately 41% of the nations in the dataset consume less than 25 kgs/capita/year; only 2% of the countries consume more than 100 kgs/capita/year (See Table 1). The average annual meat consumption within the data set is in the United States at 118.9 kgs and the highest meat consumption per capita per year in the data set is in the United States at 118.9 kgs and the lowest is in Bangladesh at 2.6 kgs.

Notable primarily for their current population and rapid economic growth are China, at 54.1 kgs/capita/year, and India, at 3.6 kgs/capita/year. Table 2 reports an estimate of the annual growth rate of per capita meat consumption for several countries, including China and India. In terms of per capita consumption, China clearly has an extremely large growth rate, 5.1%. India’s growth in consumption is much lower, less than 1%. Although our data do not investigate this dynamic, the ethnic and religious demographics (specifically, vegetarianism) in India may play a role in keeping this growth low (at least to date). Brazil, often mentioned alongside China and India for its high economic growth, has a growth rate of 3.3%. The United States has a growth rate of 0.62%, although Norway, a country with a higher per capita income than the United States in 2009, has a growth rate of 1.6%. This modest sample of five countries shows no discernible pattern; for example, it is not true that the wealthier countries have a slower growth rate in meat consumption.

**The Bivariate Relationship in the Cross-Section (2002)**

A scatter plot of meat consumption and per capita income for 149 countries in 2009, with a fitted polynomial curve, reveals the possibility of a Kuznets relationship (see Equation 1). While a downward curve fits the data, it is clear that there is much variation about this curve. To rigorously consider the Kuznets hypothesis, we estimate the following regression in order to hypothesis test the significance of the coefficient on the polynomial term, which would distinguish the relationship from a basic linear form:

\[
\text{Meat} = a + \beta_1 \text{Income} + \beta_2 \text{Income}^2 + \epsilon
\]  

(1)

Results from this regression for the high income and full sample reveal a statistically significant coefficient on income squared (see Table 3). Further, using these estimates we can solve for an apex or turning value for the full sample curve at approximately

| Table 1 Frequency table for per capita meat consumption (2009). |
|----------------|----------------|-----------|
| Kilograms | Count | Percent |
| 0–25  | 60   | 37.50    |
| 25–50 | 36   | 22.50    |
| 50–75 | 30   | 18.75    |
| 75–100| 22   | 13.75    |
| 100+  | 12   | 7.50     |
| Total | 160  | 100.00   |

\(^4\) The “turning point” (or “apex”) income is computed from the polynomial regression output by solving for, and setting to zero, the first derivative of estimated meat consumption with respect to income. So that:

\[
\frac{d (\text{e})}{d (\text{Income})} = b_1 + 2b_2 (\text{Income}^*) = 0
\]

\[
\text{Income}^* = -\frac{b_1}{2b_2}
\]

Estimated meat consumption = \(a + b_1 (\text{Income}) + b_2 (\text{Income})^2\)

\[d (\text{est-meat})/d (\text{Income}) = b_1 + 2b_2 (\text{Income}^*) = 0\]

\[\text{Income}^* = -b_1/2b_2\]

\[\text{Estimated meat consumption} = a + b_1 (\text{Income}) + b_2 (\text{Income})^2\]
Table 4 Income "inflection" point and maximum meat consumption.

| Parameter                        | Full Group | Low Income | High Income |
|----------------------------------|------------|------------|-------------|
| Inflection Income ($PPP)         | $40,043    | $3,566     | $55,606     |
| Maximum Meat Consumption (pounds)| 100        | 32         | 102         |

Note: In the case of "high income" a linear relationship, i.e. no turning point in the data, cannot be excluded. The maximum meat consumption is computed at the inflection point income.

US$43,901, a value quite a bit higher than the US$15,000 suggested by Vinnari et al. (2005) for EU countries. In addition, with the full sample, the maximum meat consumption—the predicted meat consumption at the apex income of US$43,901—would be 89 kgs (Table 4). Because, as the results will discuss, the variables for urban population and agricultural land use may be significant in a regression for meat consumption, to check the robustness of the turning point estimate we re-estimated the equation, including those variables. With these variables included—and evaluating the expected meat consumption at the sample means for urbanization and agricultural land use—we find that meat consumption in the full sample decelerates at an income of US$45,263 (and annual meat consumption of 84 kgs). Taken together, the results from these two models show that a country would not be predicted to reach the Kuznets apex until it reached a per capita income of more than US$40,000, a long journey for many developing countries.

The clustering of observations at the low end of the income scale, however, suggests that dividing the dataset may allow for more insights (see Equations 2 and 3). Therefore, we re-estimate our regression model after dividing the data between "high-income" and "low-income" countries. We use US$5,000 per capita as the dividing income. The average annual per capita meat consumption within the low-income countries is approximately 18 kgs; within the high-income group the yearly mean is approximately 59 kgs. Notably China, within the low-income group, has an annual per capita meat consumption that is more than twice the low-income group average. The results of these split regressions are given in Table 3.

As we did with the full sample model, for the split models we solve both for the income at which the data suggests an inflection point (see Table 4), or downturn in meat consumption, and for the maximum meat consumption at the inflection point. According to these results, the low-income countries would not see a Kuznets curve relationship; in fact, for these countries, neither income variable is significant in the regression. For the high-income countries, with only the income variables in the regression, a turning point would be expected to occur at an income of US$49,848, with a predicted annual meat consumption of 88 kgs. When variables for urbanization and agricultural land use are again added to the model, meat consumption is expected to decelerate at a smaller income of US$39,809 with a predicted maximum meat consumption of 65 kgs per year.

To test the consistency of our results with previous findings in the literature, we further estimate income elasticities with the ln/ln regression specification:

\[
\text{Ln}(\text{Meat}) = \alpha + \beta_1 \text{Ln}(\text{Income}) + \varepsilon \tag{2}
\]

Our overall results are largely similar to the literature-review values. In all cases, our estimates suggest that meat consumption is inelastic (< 1) with respect to income. The results for these elasticities are given in Table 5. According to our results, for the full set of countries, a 1% increase in income would increase meat consumption by 0.557%. Our point estimates suggest that income elasticity for high-income countries, at 0.487, is actually lower than for low-income countries, 0.525. As their confidence intervals overlap, though, we cannot rigorously conclude that the income elasticity is actually different across income groups.

### Panel-Data Analysis (1980–2002)

In this section, we consider extending our results, both to a panel-data set for all our countries with a maximum of 30 years for each country, as well as to a broader regression specification. In this broader specification we add two variables, measuring overall land area and the percent of a country’s population living in an urban area. In our dynamic model, these variables fit our goal to model more critically both land and the spatial use of land within a country. By modeling the spatial use of land, we hope to capture a proxy for the potential cost of resources used for animal husbandry, land area, and, with the data on urbanization, a measure of population concentration and potential industrialization of the domestic economy. Beck & Sieber (2010) further discuss the importance of spatial land and its impact.

Note: In the case of "high income" a linear relationship, i.e. no turning point in the data, cannot in the regression. For the high-income countries, neither income variable is significant in the regression. The results for these elasticities are given in Table 5. According to our results, for the high-income countries, at 0.487, is actually lower than for low-income countries, 0.525. As their confidence intervals overlap, though, we cannot rigorously conclude that the income elasticity is actually different across income groups.

### Table 5 Estimated income elasticity.

| Parameter | Full group | Low Income | High Income |
|-----------|------------|------------|-------------|
| Note: Max and min form 95% confidence interval. | | | |

| Parameter | Full group | Low Income | High Income |
|-----------|------------|------------|-------------|
| Inflection Income ($PPP) | $0.5974 | $0.6565 | $0.3745 |
| Max | 0.5348 | 0.4607 | 0.2504 |
| Min | 0.6601 | 0.8524 | 0.4986 |

Note: Max and min form 95% confidence interval.
on human geography. We also add a time trend to estimate an average increase and growth rate over time. The panel-data approach allows us to consider information on the actual growth paths of our countries. For our panel results, we estimate the base regression for Model 1:

\[
Meat = \alpha + \beta_1 Income + \beta_2 Income^2 + \beta_3 \quad (3)
\]

\[
Land + \beta_4 Urban + \beta_5 Time + \epsilon
\]

In Model 2, we estimate income elasticity by using the natural log of meat for the dependent variable and replace the variables for income and income squared with the natural log of income. Results are given in Table 6.

In Model 1, again income is positive and significant as well as the variables urban and land. The positive coefficient on land coincides with the notion that more land-rich countries may find animal husbandry less expensive. The positive coefficient on urbanization may indicate further impacts of market structures, transportation efficiencies, and industrialization, beyond simply income growth. It may also indicate a difference between tastes and preferences of urban versus rural residents, consistent with York & Gossard (2004)—but contrary to Le (2008)—in which urban residents prefer more meat consumption.

The polynomial term is negative and significant, again indicating an inflection point, and the magnitude is somewhat different from the cross section: results from the panel regression suggest an inflection point at an income of US$36,375. Again these results, and indicated incomes, differ dramatically from the findings of Vinnari et al. (2005). For countries in the low-income group (which showed no deceleration in the tendency for meat consumption in the cross-section) there are potentially many years before a per capita income of over US$35,000 will be reached, meaning, based on these results, there can be no expectation of moderation in meat consumption for many countries in our sample. Interestingly, time is not statistically significant, indicating there is no robust estimation of an increase in per capita meat consumption.

In Model 2, our estimate for income elasticity, 0.577, is similar to the cross-section, still indicating that meat consumption is inelastic with respect to income. Using the ln (meat) model, the coefficient on urban, 0.006, can be interpreted as indicating that a one percentage point increase in a country’s population living in an urban area would result in a 0.6% increase in per capita meat consumption. Here the time trend is significant and the point estimate of 0.004 indicates an average growth rate per year of 0.4% in meat consumption for this panel of countries.

### Table 6 Dependent variable: per capita meat consumption.

| Parameter      | Model 1       | Model 2 (ln)  |
|----------------|---------------|---------------|
| Intercept      | 2.7548***     | -0.6246***    |
| Income         | 0.0028***     | -0.1183       |
| Income squared | (0)***        | -0.0001       |
| ln (income)    | 0             | 0.4041***     |
| Land           | 0.0002***     | (0)***        |
| Urban          | 0.2764***     | 0.0112***     |
| Time           | -0.0345       | -0.0008       |
| N              | 3132          | 3132          |

Note: Standard errors reported in parenthesis. ***, ***, and **** indicate p-values less than 0.10, 0.05, and 0.01 respectively.

### Conclusion

When considering the possibility of a Kuznets curve in cross-national meat consumption, our strongest results are found in the cross-section full group and high-income countries. In the full sample, our cross-section results suggest an inflection in meat consumption at US$45,263; however, our fuller sample results across time, including land area and urbanization, suggest a lower income of US$36,375, still not encouraging for those concerned about the resource cost of meat consumption. In our sample of 150 countries for 2009, only eight countries (or 5.4% of the sample) actually had a per capita income higher than US$36,375; only three countries had a per capita income higher than US$45,263. It may be true, however, that from a sustainability point of view, increasing food production in non-tropical zones might reduce pressures on tropical forests, as economic drivers hold great sway over deforestation, and ecologically friendly economic incentives could play an important part in slowing forest loss (Lambin & Meyfroidt, 2011).

These mixed results do not provide overall a compelling argument that consumer demand for meat experiences a structural change at an environmentally advantageous level along a country’s income path. If income growth brings with it higher education (and literacy) levels and increased labor participation in professional occupations, there is little evidence, in this cross-national study, to suggest that this has caused a change in behavior either due to a resultant broad understanding of the health or environmental consequences of meat consumption. Nor are we able to pick up any deceleration that could be caused by
the price impact of increased global demand. The results on the impact of urbanization in our panel study suggest even further that, in addition to income growth, rural-urban migration fuels meat consumption. This is especially concerning as, even stronger than the trend of income growth in low-income countries, has been the overwhelming urbanization in the developing world. An important area of future research would be to investigate whether age dynamics within developing countries influence meat consumption, as developing countries tend to have much younger populations than in higher income countries; a negative relationship was found for the United States by Gossard & York (2003). The 2003 study concluded higher meat consumption occurs in youthful countries with growing economies.

The lack of what appears to be an encouraging inflection point in meat consumption opens the door to a broader public-policy debate. Free-market advocates suggest that markets should take care of themselves: higher demand for meat should drive prices for meat products higher and, as was found in earlier studies, consumers do respond to price in their choices to consume meat. As the environmental consequences of meat on land, air, soil, and water resources have far-reaching, global consequences, however, policy makers may find it more compelling to intervene in the formation of consumer demand either through direct policies further targeting the price of meat through taxes or through indirect policies of broad environmental education and health awareness, as well as the elimination of subsidies for the meat industries. Importantly, while many concerns suggested above relate to income and urbanization growth in developing countries, our results strongly indicate no reason to neglect the patterns of meat consumption in high-income countries either. The social factors and preferences that may drive a Kuznets curve in different measures of pollution seem still absent in meat consumption in these countries. Reasons for this difference can be hypothesized: perhaps air pollution is more visible and obvious than the environmental damage caused by animal husbandry, or perhaps the issues of animal rights and ideological vegetarianism obfuscates, for many, the need to consider this issue beyond the individual choice to eat meat.

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