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**The Income-Temperature Relationship
in a Cross-Section of Countries and
Its Implications for Global Warming**

by

John Horowitz

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February 14, 2001

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The Income-Temperature Relationship in a Cross-Section of Countries and its Implications for Global Warming¹

1. Introduction

Hotter countries are poorer on average than cooler countries. The broad form of this relationship is easy to recognize – Europe is both cooler and richer than South America, which is both cooler and richer than Africa – and it has played an important, although often indirect, role in several recent studies of development and growth. In these studies, social scientists have sought to understand how climate and geographical features as well as historical accident have affected the fate of nations. Gallup, Sachs, and Mellinger (GSM) label this the “new geography.” Nordhaus gives a particularly wide-ranging discussion of how temperature has been viewed as a factor in economic activity, particularly at the individual level, as when worker or student performance is affected by ambient temperature.

The specter of global warming makes temperature’s role in the economy especially important, and it is for this reason that it deserves especially thorough scrutiny. One way of gauging how warming will affect an economy is to look at the economic performance of countries that are warmer. If global warming is going to make Cameroon’s temperatures (73.8°) more like the Central African Republic’s (78.3°), then the difference between Cameroon’s income (\$1,444) and the CAR’s (\$1,1131) may give a measure of the costs of global warming. Such direct, econometric evidence has rarely been exploited in research on global warming. Even if it must eventually be tempered by other explanations, such a comparison is highly valuable. In this paper, we look at data

¹We thank Marc Nerlove for helpful comments and Jeremy Castle for research assistance.

for 156 countries.

There are, of course, many possible reasons why hotter countries are mostly poorer, such as climate's effects on disease, agriculture, capital depreciation, worker productivity, or human behavior, say in the form of culture or institutions. The number of candidate pathways is large. The most important distinction, however, is not among these various paths but between effects that are *contemporaneous*, that is, due to current climate, and those that are *historical*, that is, due to past climate. Historical effects are those that arose because climate played a role at some time in the past, but this role is no longer important. In other words, cool climates may have given some countries a head-start but the reason for that head-start no longer affects current economic performance. Climate's past role would still be observable if because of it cooler countries acquired higher levels of capital or better institutions, which would then lead to higher current incomes. Since current climate is similar to past climate in the cross-section, a relationship between current temperature and income would still appear in the data.

The distinction between contemporaneous and historical effects is crucial because only when climate's effects are contemporaneous does the cross-sectional income-temperature relationship yield evidence about possible economic effects of global warming. Note that all of the candidate pathways – disease, agriculture, capital depreciation, worker productivity, institutions – could conceivably be either contemporaneous, historical, or a combination of both.

The widespread belief is that the income-temperature relationship is mostly historical. We generally concur. Acemoglu, Johnson, and Robinson (AJR) have recently made great gains in identifying a specific historical path. They convincingly argue that

mortality rates of early colonizing settlers had a profound effect on the institutions that were set up in those colonies. These institutional differences persist to this day (because of transactions costs, collective choice problems, and irreversible investment), they argue, and have strong effects on current per capita incomes. Because early mortality and average temperature are highly correlated, the mortality-institution-income relationship also manifests itself as an income-temperature relationship. The AJR argument that *institutions* form the path between historic conditions and present incomes was also made by Choinière and Horowitz, who argued that if the historical explanation of temperature is correct, the data suggest that cooler countries did not simply accumulate higher (physical) capital stocks: they must have acquired better institutions as well.

There is, however, sufficient evidence to warrant continued examination of the income-temperature relationship. First, we find a strong income-temperature relationship *within* OECD countries, a result that does not appear to be predicted by AJR's colonial mortality model and that other authors seem to disavow. Second, we find that the income-temperature relationship is essentially the same within the OECD and non-OECD countries, a striking yet unremarked and as-yet unexplained result. Third, we find an exceptionally strong income-temperature relationship within the fifteen countries of the former Soviet Union, where colonial institutions would seem to have been wiped out. These findings, along with several related results, are the subject of this paper. It is also worth noting that a significant relationship between income and average temperature exists *within* the United States (Horowitz; Ram 1999), another situation where cross-sectional differences in institutional quality, inherited from past institutions, would not seem to be a major factor. This finding is not taken up in the current paper.

Other results confirm the AJR findings, although even these often suggest a second, separate role for temperature. In regressions with both temperature and settler mortality data as explanatory variables, we find that settler mortality provides greater explanatory power than temperature: but temperature continues to exhibit a moderately large effect on income. When we look at countries not included in AJR's data set, many of which are not former colonies, we continue to find roughly the same income-temperature gradient.

We do not propose a specific hypothesis, either contemporaneous or historical, for the findings we uncover. Instead, we focus on identifying the main international evidence that does not appear to be explained, so far, by the AJR historical model. We then assess its implications about the costs of global warming. In the process, we discuss the role of temperature in economic activity – a role that we find both persistent and consistent – and the issues involved in uncovering and interpreting that role.

2. Literature

This literature has looked at both income and growth, but the questions and approaches have been similar and so we discuss them as one. Most such papers have focused on either the role of latitude (Hall and Jones; Nordhaus; Ram, 1997, 1999; Theil and Chen; Theil and Finke; Theil and Seale), the percentage tropical (GSM), or a simpler dichotomy between temperate and tropical countries (Masters and McMillan). A common result: "Affluence tends to decline when we move toward the Equator" (Theil and Seale, p. 403). Masters and McMillan use a temperature- rather than latitude-based definition of the tropics.

Authors differ on why latitude (distance to the equator) has such a strong effect, although its correlation with temperature – with temperature then affecting disease or agriculture – is at the heart of most explanations. Thus, our treatment of temperature as a continuous variable should improve on these studies. Only daylight is more closely correlated with latitude. Daylight could, of course, have significant on economic performance (see Nordhaus' cite of Woodruff), but this pathway does not appear to have been taken very seriously. Distance to Europe, another variable correlated with latitude in the northern hemisphere, is also unlikely to explain the income-temperature or income-latitude relationship, since there is a significant income-temperature gradient among the 35 countries of the southern hemisphere, where cooler countries are farther from Europe.

AJR's explanation for the observed connection between temperature and income has already been mentioned. Hall and Jones make a similar argument for the historic role of distance from the equator, based on western European influence on institutions developed when these countries were colonized. They suggest that "Western Europeans were more likely... to settle regions of the world that were sparsely populated at the start of the fifteenth century" and in areas that were "broadly similar in climate to Western Europe" (p. 101). Both items are likely highly correlated with colonial mortality and also with temperature. The Hall and Jones explanations would clearly benefit from an empirical analysis of historic population densities or climate similarities; as it stands, their testable implications, for this paper's purposes, are not as sharp as AJR's.

A few studies have looked more explicitly at temperature's role. Masters and McMillan look at the effect of numbers of frost-free days. Frost has a direct role in reducing pests and pathogens that may be missed by a focus on average temperature.

They show that frost free days has a significant effect on population density and cultivation intensity even when average temperature is included as an explanatory variable. They do not look at joint effects of temperature and frost-free days on incomes.

Other papers that use continuous temperature measures as explanatory variables include AJR, who argue that temperature is insignificant in explaining income in their joint model of institutional quality and income once colonial mortality's effects are accounted for. Nordhaus looks at average temperature for forty countries; we refer to one of his main conclusions in Section 4.

There is, of course, a vast non-econometric literature on the relationship between temperature, the tropics, and economic development. See AJR, Kamarck, and Nordhaus for particularly good summaries of historical views.

Implications of Using Country-level Data. Almost all of these studies, including ours, use per-capita country-level data. This approach implicitly assumes that a person living in country A can move to country B and earn the per-capita income of country B. This approach is standard, if not always reasonable. Given such an approach, it is not surprising that country-level factors, such as institutions, turn out to have great power as explanatory variables; the regressions are predisposed to find country-level explanations. Previous authors appear not to have recognized this subtle bias. Of course, the country would be the correct unit of analysis if country-level variables are indeed the main determinants of income and growth. Perkins and Syrquin note that the definition of a country is itself endogenous. This endogeneity would seem to allay some of the problems involved in focusing at the country level.

(We should also note that our analysis, as well as most of the rest of the

literature's, also implicitly assumes that our "confidence" in a random person's ability to earn the income in his country is roughly the same across all countries. This assumption is obviously faulty but we do not analyze alternative treatments here.)

As an alternative, GSM and Nordhaus discuss GDP per unit area, although neither approach is econometric. Nordhaus claims that "climate may have an effect on income [per square kilometer], but the effect is swamped by other variables" (p. 364), but it appears that he calculates income per area as a country's GDP divided by its area, rather than as the GDP of each specific area. We leave this subject for future research.

The income-temperature relationship within a given country should be particularly informative because it holds constant country-specific effects. Little analysis appears to have been conducted so far, although the general pattern in the U.S. is recognizable without statistical analysis: Cooler parts of the U.S. are richer, on average. Ram (1999) used distance from the equator to explain differences in per-capita personal incomes by state in the U.S. Horowitz looked at the income-temperature relationship at the MSA level. In a regression of log of nonfarm earnings per capita on log of average temperature and log population, he found that a one-percent increase in temperature is associated with a 0.54 percent decrease in earnings. This finding is preliminary, however, and the per capita measure is based on population rather than the size of the work force, which is important because there are likely more retirees in warmer MSAs.

Mendelsohn, Nordhaus, and Shaw (MNS) looked at the relationship between agricultural land values in the U.S., at the county level, and sixteen climate variables: four temperature and four precipitation variables, plus squared terms. They found that higher temperatures are not always associated with lower land values.

3. Data

We conduct cross-sectional regressions of income per-capita against temperature and other explanatory variables for 156 countries in 1999. The data are shown in Figure 1. Summary statistics and countries in each of the categories are in the Appendix.

Dependent variable. As our income measure, we use 1999 GNP per capita measured using purchasing power parity, published by the World Bank. When necessary, we convert GNP per capita to GNP using 1999 population from the World Development Indicators database. Previous studies have typically focused on GDP, which would likely be a better gauge for temperature's effects; in other words, we would expect the GDP-temperature relationship to be even stronger than for GNP. We use GNP because it is the central focus of the World Bank's data collection. Most previous papers have used the Penn World Tables.

There are several temperature-related issues that arise in our measure of income. Heating expenditures in cold countries are considered a "plus," but the amenity value of the climate when space heat is not needed is not included. This difference has the effect of exaggerating the utility losses from higher temperatures. Put another way, the income-temperature relationship and any implied measure of the "cost" of higher temperatures excludes the amenity value of climate. Air-conditioning expenses cause a problem in the opposite direction but on a global scale these are much less important than heating expenses.

The income measures also exclude other non-market goods such as pollution and greenery, and drinking water quality and quantity are only partly accounted for. To the extent that these goods are affected by temperature, the observed income-temperature

relationship will differ from the true utility-temperature relationship. If pollution's effects are exacerbated by warm temperatures or if the value of drinking water is higher in warmer countries, then the observed income-temperature will underestimate the consequences of higher temperatures.

Temperature. Many different climate measures are possible. Since our interest is in global warming, some measure of long-run average temperature will be the most useful single climate variable. It is important to note that the "best" climate measure(s) is both a question and an answer. That is, if economists had a better understanding of how climate affects incomes, then it would be clear which climate variables would be appropriate for regressions. But developing this understanding is the purpose of those regressions in the first place.

We use long-run average temperatures in the capital city as reported in www.worldclimate.com. Alternatives to using the capital city's temperature pose the following sorts of problems. A country's temperature averaged over the entire country will include economically irrelevant areas (think of Canada.) Weighting temperatures by the amount of economic activity in an area would be extremely difficult given the lack of spatially dense economic data for much of the world and would introduce a great deal of endogeneity, since the location of economic activity is essentially what we hope to explain. Therefore, we focus on a single point in each country.

We chose the capital city because it seemed the "most exogenous" and still likely to be representative of the conditions under which economic activity takes place in each country. A country's geographic center, for example, is exogenous but not necessarily representative of the temperatures under which economic activity occurs. The largest

city may be more representative but is "less exogenous" than the capital city. For these reasons, we focus on the capital city's temperatures.

Our focus on temperature at a single location is the most problematic for countries with a large degree of temperature variation. An interesting question, deserving of further research, is whether countries have tended to locate their capitals in the cooler part of their countries, as Australia, China, and India appear to have done.

Temperature data were not readily available for a few countries, mostly small island countries. Because of their smallness, and to keep the temperature data consistent, we decided not to pursue these. The ten countries with GNP data that we exclude are Antigua and Barbuda; Bermuda; Brunei; Dominica; Maldives; Seychelles; Swaziland; St. Kitts and Nevis; St. Lucia; and St. Vincent and the Grenadines.

Other explanatory variables. Our investigation of temperature's role uses a sparse reduced-form. Because temperature is so clearly exogenous at the country level, we try to use only explanatory variables with a similar degree of exogeneity. Other commonly used explanatory variables such as savings rates, population growth, or measures of institutional quality or "social character" are themselves possibly influenced by temperature and so either should not be included as regressors or else should be modeled jointly with income. We focus on three sorts of regressors besides temperature: resource endowments; former Soviet bloc; and tourism.

Oil production data are from the Energy Information Administration's *International Energy Annual*, Table G2. We used 1998 production of crude oil, natural gas, other liquids, and refinery processing gain, in thousands of barrels per day. Countries with no entry were given a value of zero. Other possible measures, such as reserves,

seemed too imprecise for our purposes and the data did not have as wide a coverage. Coal production data are also from the *International Energy Annual*, Table F5. We used 1998 production in trillions of BTUs.

In general, "form of government" should be considered endogenous. Yet at least one form might be considered exogenous, namely being part of the former Soviet bloc (FSB). We use a standard definition of the FSB that includes the fifteen former Soviet republics, seven formerly communist European countries (Albania, Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia), Mongolia, and three countries of the former Yugoslavia (only Croatia, Macedonia, and Slovenia are included in our data), which were not truly bloc countries but whose economies were sufficiently similar that they warrant being included with the bloc.

Temperature-driven tourism – as when someone from a cool country visits a hot country, primarily for its beaches and sunny weather – is an example of a role for temperature very different from the ones described in the introduction. We attempt to separate these roles by incorporating a measure of tourism as an explanatory variable. We looked at two sources of tourism data: International tourism receipts by country of destination (1998), collected by the World Tourism Organization; and expenditures by international visitors on goods and services in a resident economy (1998), collected by the World Travel and Tourism Council. We calculated and then ranked countries based on tourism receipts as a percentage of GNP. The WTO and WTTC rankings were almost identical. The calculated percentages seem questionable, however; for example, French Polynesia, which has an extremely high standard-of-living based on the GNP (comparable to Italy's), had only 7 percent of its GNP as tourism receipts.

We therefore use a dummy variable for whether the country has a tourism-based economy. All countries with a percentage at least as high as Fiji's were given a dummy variable of 1. Thus, the following eleven countries are considered tourist economies in our data: Bahamas, Jamaica, Cyprus, Malta, Grenada, Vanuatu, Belize, Croatia, French Polynesia, and Fiji. The decision to choose Fiji as the cut-off is arbitrary but not controversial because the countries just below the cut-off were Lebanon, Singapore, and Austria, none of which represents the kind of economy we wish to account for. All countries other than these eleven are non-tourism economies.

Sample selection. There are 40 countries for which GNP data are not reported. Some of these countries contain significant population (Afghanistan, Burma), unlike the missing-temperature countries. Since these countries tend to be poor, often quite poor, their absence from the data has the potential to affect the estimated income-temperature relationship if they have temperatures different from other poor countries. We have ready temperature data for 23 of these countries, including all that are large in area or population except for Cuba. The population-weighted average temperature for these is 70.3° , which is higher than the population-weighted average temperature for all non-OECD countries; the unweighted average is 70.7° . Thus, while it is not possible to tell what effect the omission has on our estimates, it is most likely that our estimated income-temperature gradient is *smaller* in absolute value than the true gradient. Cuba's average temperature is around 77° , so its exclusion from these calculations further suggests that the estimated income-temperature gradient will be smaller than the true one.

4. The Income-Temperature Relationship

4.1 Results

The basic relationship is shown in regressions 1 and 2 in Table 1. We run separate regressions for the OECD and non-OECD countries. We first treat the Czech Republic, Hungary, and Poland as non-OECD countries. This treatment is justified given that former Soviet bloc countries are statistically indistinguishable from non-OECD countries once temperature is accounted for (regression 2). Leaving these countries in the OECD set has little effect on our conclusions, as shown in Tables 2 and 3 where these countries are included in the OECD set.

For simplicity, we sometimes refer to the absolute value of the coefficient on $\ln(\text{TEMP})$ as γ . This parameter measures the predicted percentage decrease in GNP for a one percent increase in the long-run average temperature.

There are two major findings. There is a substantial income-temperature gradient within OECD countries and this is, for all practical purposes, *identical* to the gradient in non-OECD countries. It may be tempting to think either that temperature would have less of an effect in developed countries ($0 < \gamma_{\text{OECD}} < \gamma_{\text{non-OECD}}$) or even that the difference between OECD and non-OECD temperatures would account for *all* of the world's observed income-temperature gradient ($\gamma_{\text{OECD}} = \gamma_{\text{non-OECD}} = 0$). Both expectations are clearly contradicted by these results.

The temperature gradient within OECD countries is unanticipated by the current literature. One might think that among developed nations, temperature's effects would be minimized by technology, health care, and the very small role played by agriculture. Nordhaus claims that "from a mean temperature of about 40° to about 65°, there is no

relationship between mean temperature and income per capita" (p. 362); his paper, however, is oriented to a discussion of climate's roles and is not a detailed empirical exploration. Masters and McMillan write that "above the 50-degree [latitude] line, the distribution [of growth] appears to be flat." (p. 1). While neither of these papers specifically claims that the income-temperature gradient for OECD countries will be flat, they clearly leave the impression that climate is supposedly unimportant for developed countries. The significance of the income-temperature gradient within the OECD is further striking because, since all of the OECD capitals are relatively cool, a lot of the worldwide temperature variation is removed.

The extreme closeness of the income-temperature relationship within the two classes of countries, OECD and non-OECD, is intriguing, if not truly bewildering. We have no ready explanation. It is not even clear, for example, whether one should look for a single underlying cause or a mix of temperature-sensitive factors – disease, agriculture, factor productivity, culture, factor endowments – of which the mix might be roughly the same between the two nation groups.

Based on the Table 1 results, it is tempting to conclude that differences in temperatures might account for most of the difference between OECD and non-OECD countries; in other words, that the structures of both types of economies are the same and that the higher wealth of OECD countries is itself a grand manifestation of the temperature effect.² Further evidence for this belief comes from the closeness of the intercepts, which are well within each other's confidence interval. Such a conclusion would be mistaken. When the regression is run with all countries, with separate intercepts and

²A randomly-chosen person living in the OECD is likely to be living in an average temperature of 53.9°, which is substantially cooler than the temperature a randomly-chosen person living in the non-OECD

slopes for OECD countries (not shown), albeit without any allowance for differences in error structures, the joint hypothesis of equal intercepts and slopes is rejected.

Regression 3 shows that the worldwide income-temperature gradient is -3.46, quite similar to the -3.42 measured by Choinière and Horowitz using 1985 data for 97 countries with no correction for oil or coal production or being a tourist economy. Therefore, being in the OECD, most of whose countries are cool, accounts for about 60 percent of the world's observed income-temperature gradient.

While it seems interesting to understand why the OECD countries are cooler than the others, we believe this difference is best viewed as historical, since it is hard to imagine a country breaking down so severely as to no longer have an OECD economy because of a change in temperature. It is slightly more plausible to imagine that global warming might delay a country's becoming ready for the OECD. In this case, global warming would be considerably more costly than the income-temperature gradients of regressions 1 and 2 predict.

4.2 Functional form

Theory gives little guide to what the likely functional form is for the income-temperature relationship. The log-log form makes for easy comparison across regressions and is implied by a steady-state Cobb-Douglas production function with temperature as an input (Choinière and Horowitz). The log-log form may seem extreme, however, because it implies that it is the percentage change in temperature that affects the percent change in incomes. This makes global warming particularly costly. A given temperature increase (say, a 1.5° F increase occurring in all countries) will be a higher

world is likely to be living in, 65.9°. (These are population-weighted averages.)

percentage increase in cooler countries, which also happen to be richer. These countries are then predicted to lose an even greater proportion of their income than poor/warm countries. Several authors have pointed out that the true relationship should be hump-shaped (Masters and McMillan; MNS; Quiggin and Horowitz) since both very hot and very cold climates will hamper economic activity. The log-log form cannot capture such a relationship.

To see the effects of allowing a richer temperature relationship, we estimated several cubics. Results are in Tables 2 and 3.

All of the cubics indeed show a cool region over which an increase in temperature raises incomes. In regression 5, the hump is at 44.0° . For regression 6 it is 44.2° . Canada, Finland, Iceland, Norway, and Sweden, which have average temperatures below 44° , are all predicted to benefit from increasing temperatures, a highly plausible result.

The predicted hump for the non-OECD countries is almost identical: 44.1° for regression 8 and 43.2° for regression 9. This is another instance in which the income-temperature relationship is essentially the same for both OECD and non-OECD countries.

The cubic estimates also predict that there is a second region of much higher temperatures over which an increase in temperature again raises incomes. This turns out to be essentially irrelevant. For the OECD countries, the second turning point is at 64° and 65.2° in regressions 5 and 6 – at the very upper range of the OECD temperatures. For the non-OECD countries, the second turning point is at 81.7° and 85.9° in regressions 8 and 9. These are the very upper range of non-OECD temperatures.

Comparative Statics. To see the consequences of different functional forms we turn to their predictions about the effects of temperature change. For a given temperature

change, we use the regression results to calculate the predicted change in GNP and multiply it by population for each country. These are then summed over the countries used for that regression and compared to current total GNP, constructed from multiplying current GNP by population for each country and summing. This procedure is also used to estimate the costs of global warming in Section 6.2

Results are shown in Table 4. We report the implied percentage change from current total GNP for a 1.5° and 3° F temperature increase (for all countries), based on regressions 1 through 9. These temperature changes are at the lower end of those predicted for global warming. Our calculations assume that populations are unchanged.

In the log-log regressions, a temperature increase will unambiguously lead to a decrease in total GNP. Furthermore, for the reasons described above, the percent decrease in GNP will always be greater than γ times the percent increase in average temperature, since a given temperature increase is a higher percentage increase in cooler countries, which are on average richer.

For the cubic regressions, a temperature increase need not lead to a decrease in total GNP since some countries are predicted to benefit. All of our results, however, show decreases in total GNP of roughly the same magnitude as the log-log model. Note that all of the cubic models predict a large temperature region in which the income-temperature gradient is *steeper* than the comparable log-log prediction.

The log-log function implies that income decreases are concave in the temperature change whenever $\gamma > 1$. In other words, a 3° temperature increase produces less than twice the income decrease of a 1.5° increase. The cubic functions do not imply concavity, but all of our results exhibit it. Such concavity makes sense, since incomes

can never fall below a survival level.

We find implied income decreases of 3.7-4.4 percent for a 1.5° F increase in OECD countries and about three-quarters of a percent less for non-OECD countries. For a 3° F increase, we find implied income decreases of 7.1-8.3 percent in OECD countries and 5.9-7.2 percent in non-OECD countries. These numbers show that the effects of temperature change are nearly linear in the change; the degree of concavity is quite small.

4.3 Other Results

Former Soviet bloc. Our results suggest that former Soviet bloc economies are not significantly different from other non-OECD economies, conditional on their temperature (regressions 2, 7, 8, and 9). This observation has not been made to our knowledge.

Oil and coal. The data contain seven OPEC members (Algeria, Indonesia, Iran, Nigeria, Saudi Arabia, U.A.E., and Venezuela). We tested whether a similar result to the Soviet bloc holds for OPEC countries. Although OPEC membership is highly correlated with oil production, it is possible to run regressions 7, 8, and 9 with an added dummy variable for OPEC (not shown); this is possible because there are several non-OPEC countries with comparable levels of per-capita oil production, such as Gabon, Congo, Bahrain, Angola, and Russia. The OPEC coefficient is small and insignificant in all three cases (t-ratios of less than 0.50). Other coefficients, including the oil per-capita variable, are essentially unchanged. We conclude that OPEC countries too are essentially the same as other non-OECD countries once oil endowments and temperature are accounted for.

(Note that if energy reserves, particularly oil, were not included in the regressions, the income-temperature gradient would likely be mismeasured, since oil and temperature

happen to be highly correlated.)

Tourism. Countries endowed with resources that appeal to tourists are significantly richer than comparable non-endowed countries.

5. Further Evidence

In this section, we look more explicitly at the historical explanation put forth by AJR. We are interested in the extent to which the observed income-temperature relationship is due to an historical effect of colonizers' mortality, which is strongly correlated with average temperature ($r=0.55$, $n=69$). We approach this in several ways. The connections between colonial mortality and past institutions or between past and current institutions, both insights of AJR, are not the focus of our research.

Two Colonized Regions. In Table 5, we examine Africa and the western hemisphere, two regions that consist almost entirely of former colonies and that should show particularly strong income-mortality effects, and thence income-temperature effects.

Results show that the income-temperature gradient is indeed large for these regions, with $\gamma_{\text{Africa}} = 2.43$ and $\gamma_{\text{WH}} = 1.82$ (regressions 10 and 11, respectively). We treat this finding as evidence in favor of the AJR explanation. It is especially interesting to note that a large and significant income-temperature gradient exists even within Africa, since a general – that is, non-econometric – view might conclude that the world's observed income-temperature gradient (regression 3) is due largely to the difference between "neo-Europe" and Africa. The previous section demonstrated that a gradient exists within the OECD; in this section, we have demonstrated that a gradient also exists within Africa. Again, it is worth noting that this finding is particularly surprising since a

lot of cross-sectional temperature variation is removed when focusing on Africa.

Countries with Mortality Data. In regressions 12 and 13, we examine countries for which AJR reported colonial mortality, based on extensive research by Curtin and also by Gutierrez. In regression 12, we include log of mortality (AJR's fourth mortality estimate in their Appendix Table A2). It is a strong predictor of current per-capita GNP and appears to have substantially greater explanatory power than temperature. In this regression, we treat OECD and non-OECD countries the same, since the mortality explanation should account for the difference between these two groups.

Temperature's effect is diminished but still relatively large, even if imprecisely measured. We find that even among these countries, strongly influenced as they were by the colonial experience, a one percent increase in average temperature is associated with a 0.9 percent decrease in per-capita GNP.

In regression 13, we show what the income-temperature relationship looks like when mortality is not included. We remove the OECD countries to allow comparison with regressions 15 and 16, discussed below. The income-temperature gradient is much larger than regression 12, of course, and is comparable to what we measure for the colonized regions in Table 5, as indeed it must be. (When we include OECD countries, so that the country sample is the same as regression 12, the temperature coefficient is - 3.06, close to the worldwide gradient found in regression 3.)

Former Soviet Union. We next looked at the fifteen countries of the former Soviet Union (regression 14), a set of countries for which the mortality explanation would be unlikely to apply, since colonial-era institutions were largely obliterated and homogeneous institutions imposed. Still, a large income-temperature gradient

appears. This is in fact the largest income-temperature gradient we measure and it is particularly striking given the small number of observations and apparent homogeneity of the sample: Not long ago, this regression would have been a within-country regression.

Countries without Mortality Data. We then looked at all non-OECD countries for which AJR do not report mortality data. This set includes countries for which the colonization experience was roughly the same as others for which there was mortality data, like Benin and Zimbabwe, and countries that were not former colonies or for which the colonization experience was much different, like China, Thailand, and Saudi Arabia.

If the data were composed entirely of these latter countries, then we would expect to find the income-temperature relationship to be roughly the same as that found in regression 12, equal to -0.91 . On the other hand, if the data were composed mostly of the former countries (*i.e.*, former colonies for which we just did not have mortality data), then we would expect to find the income-temperature gradient to be more like that found in regression 13, since it would be capturing both mortality and temperature effects.

For the mix of countries that we analyze, we expect something in between. We look only at non-OECD countries because, without mortality data, we have no other way to capture the difference between the OECD and non-OECD.

Results are shown in regressions 15 and 16. In regression 15, the income-temperature gradient is -1.04 . In regression 16, we add former Soviet bloc countries. The gradient is essentially unchanged at -1.05 , although now much more precisely measured. (This is again evidence that FSB countries are like other non-OECD countries once temperature is accounted for.) These coefficients are larger than regression 12 and smaller than regression 13, as predicted.

6. Conclusion

6.1 The Income-Temperature Relationship: Findings

We have looked at several manifestations of the income-temperature relationship in a cross-section of countries. The substantial income-temperature gradient for OECD countries and its similarity to the income-temperature gradient for non-OECD countries, two related findings, are particularly noteworthy and appear not to have been recognized in the literature. When a cubic pattern is estimated, OECD and non-OECD countries show similar patterns, roughly speaking: A plausible set of temperatures where incomes are increasing in temperature, including for example Canada and Finland, and incomes decreasing in temperature for the rest of the relevant temperature range. We also show that non-OECD countries of the former Soviet bloc are similar to other non-OECD countries once temperature's effects are accounted for.

Our results also demonstrate the income-mortality connection. Colonial mortality, as reported by AJR, is strongly correlated with average temperature and, for the set of countries for which comparison is possible, a stronger predictor of current income than temperature. Formerly colonized regions such as Africa and the western hemisphere show especially large income-temperature gradients.

Nevertheless, a further role for temperature appears to exist. Even when mortality is included as a regressor, the temperature effect is relatively large, -0.9, although imprecisely measured. When temperature's role is estimated for countries for which mortality data are unavailable, it falls between this estimate and the estimate for those former colonies when mortality is not accounted for.

The large income-temperature slope within the former Soviet Union is striking,

especially since these countries were not subject to the same pattern of colonial institutions as much of the rest of the world. The magnitude is similar to the slope when OECD and non-OECD are measured together (regression 3), which suggests that a substantial part is probably due to some economies being "more European." Exactly what this entails is as yet unknown. This explanation slightly weakens our claim that the former Soviet bloc (and by extension, the former Soviet Union) is similar to the rest of the non-OECD except for temperature.

Our conclusions must be stated carefully. There is diffuse yet strong evidence that the relationship between income and temperature, observed in various cross-sections, is due to more than just the effect of temperature on colonial mortality. The pathway for this relationship is unknown. Colonial mortality is not the only possible historical role for temperature, although it is compelling as such. AJR show that current institutions have no additional explanatory power for current income once the effects of colonial mortality are accounted for, and they argue against the historical (and empirically untested) explanations of Hall and Jones. Thus, it appears to us that the remaining income-temperature gradient is most likely contemporaneous. Our best measure of this contemporaneous effect is that a one percent increase in temperature leads to a -0.9 percent decrease in per capita income.

6.2 Implications for Global Warming

When the income-temperature relationship reflects the effects of contemporaneous temperature, comparative statics calculations yield estimates of income changes caused by global warming. When $\gamma = 0.9$, a 1.5° F increase in temperature leads

to a 2.35 percent decrease in world GNP. A 3° F increase leads to a 4.58 percent decrease, and a 4.5° F increase leads to 6.70 percent decrease. These calculations assume that the temperature increase is the same across all countries, although some global warming models predict different increases depending on latitude, and that populations are unchanged. These are our best guesses of the effects of global warming, conditional on predicted temperature changes.

These measures are roughly linear in γ . If $\gamma = 1.35$, as in regressions 1 and 2, then a 3° F increase leads to a 6.78 percent decrease in world GNP. If $\gamma = 0.45$ (a roughly equal distance on the other side of -0.9 and close to the coefficient measured for MSAs in the U.S.), then a 3° F increase leads to a 2.32 percent decrease in incomes.

We have not specified the mechanisms through which temperature's effects are felt. Many factors may contribute, including disease, agriculture, capital depreciation, worker productivity, and institutions. Untangling these is a task for further research. If higher temperatures delay a country's becoming an OECD-type country, the costs of global warming will be larger.

Cross-Sectional Measures and Tourism. Our procedure for measuring the costs of global warming has several important limitations. In the absence of trade (clearly an unwarranted assumption here), the cross-sectional method would yield an *underestimate* of the effects of temperature change, because it does not include the costs of adjusting to a new temperature. It assumes that countries can costlessly and immediately develop infrastructure to match a new climate, as countries *currently* operating at that temperature have done.

In the presence of trade (but without adjustment costs), the cross-sectional model

may produce either an under- or overestimate of the effects of temperature change. The reason is that it is the vector of temperatures that determines trading patterns and incomes. Thus, any change in temperature is "out of sample" and its effects unknown. The smaller is the amount of temperature-dependent trade, the smaller will this effect be and the closer will be the cross-sectional estimates to the true effects of temperature on countries' economies, except for adjustment costs.

This concern is why we have removed the effects of temperature-dependent tourism in our regressions. Temperature-dependent tourism is, by definition, temperature-dependent trade, since it involves people from one (cooler) country traveling to another country that is warmer.

6.3 Further Research

We see two related goals for further research: a conceptual and then an empirical model that allows trade, including temperature-dependent (*i.e.*, temperature-generated) trade, and that allows both within-country and between-country temperature effects. Empirical studies of income variation within countries, particularly for countries like the United States or China which have large cross-sectional temperature variation, should be particularly useful for understanding the possible economic effects of global warming.

The specific ways in which temperature affects economic performance, both contemporaneously and historically, are just beginning to be understood and warrant much more research.

Figure 1. The Income-Temperature Relationship for 156 Countries

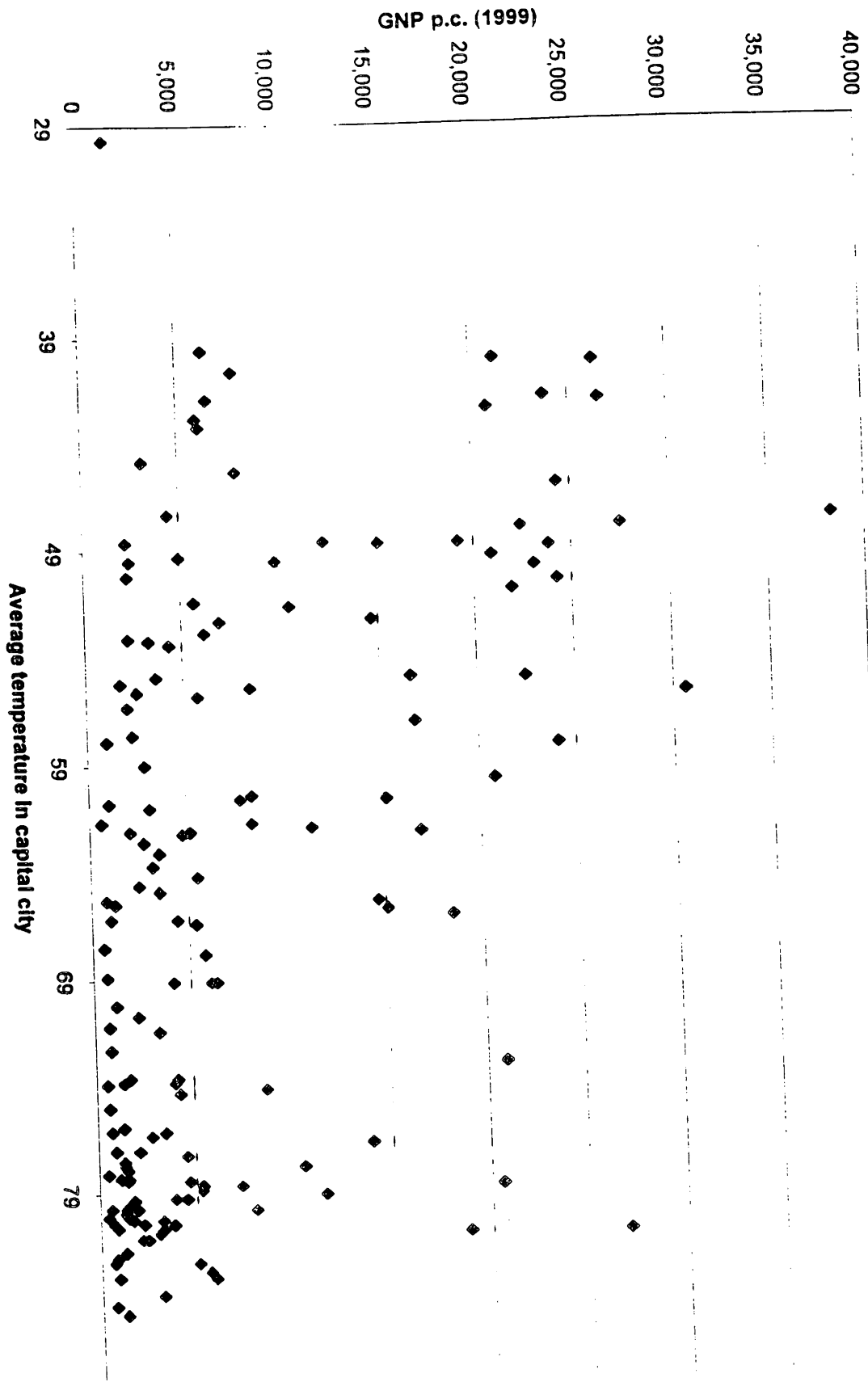


Table 1. The Income-Temperature Relationship for 156 Countries

Dependent variable: ln(GNP) in 1999	#1 OECD except Czech. Hungary, & Poland	#2 non-OECD plus Czech. Hungary, & Poland	#3 All
Intercept	15.20 (6.71)	13.46 (5.33)	22.72 (13.66)
ln(T)	-1.36 (2.35)	-1.35 (2.29)	-3.46 (8.80)
Former Soviet Bloc	—	-0.09 (0.30)	-1.03 (4.52)
Oil per capita	0.04 (0.07)	3.01 (3.74)	2.24 (3.18)
Coal per capita	0.11 (0.93)	1.01 (2.19)	0.55 (2.24)
Tourist economy	—	1.25 (4.54)	1.17 (4.03)
Number of observations	26	130	156
R ²	0.23	0.28	0.43

t-ratios in parentheses.

Table 2. The Income-Temperature Relationship for 29 OECD countries

Dependent variable:	#4 ln(GNP)	#5 ln(GNP)	#6 GNP/1000
Intercept	14.83 (6.73) ^a	-8.34 (0.29)	-315.71 (0.66)
ln(T)	-1.26 (2.25)	--	--
T	--	1.09 (0.64)	19.82 (0.70)
T ²	--	-2.09×10 ⁻² (0.64)	-3.76×10 ⁻¹ (0.69)
T ³	--	1.29×10 ⁻⁴ (0.61)	2.29×10 ⁻³ (0.65)
Former Soviet Bloc	-0.79 (3.46)	-0.84 (3.50)	-13.79 (3.42)
Oil per capita	0.07 (0.12)	0.13 (0.23)	3.17 (0.34)
Coal per capita	0.10 (0.87)	0.10 (0.86)	1.60 (0.79)
R ²	0.40	0.42	0.43

t-ratios in parentheses.

Table 3. The Income-Temperature Relationship for 127 non-OECD countries

Dependent variable:	#7 ln(GNP)	#8 ln(GNP)	#9 GNP/1000
Intercept	13.72 (5.36)	1.43 (0.22)	-11.60 (0.36)
ln(T)	-1.41 (2.35)	—	—
T	—	3.91×10^{-1} (1.13)	9.67×10^{-1} (0.55)
T ²	—	-6.83×10^{-3} (1.14)	-1.68×10^{-2} (0.55)
T ³	—	3.62×10^{-5} (1.08)	8.67×10^{-5} (0.55)
Former Soviet Bloc	-0.15 (0.51)	-0.23 (0.68)	-1.38 (0.79)
Oil per capita	3.02 (3.74)	3.09 (3.83)	17.26 (4.18)
Coal per capita	0.90 (1.56)	0.83 (1.44)	2.89 (0.98)
Tourist economy	1.25 (4.53)	1.27 (4.60)	6.39 (4.53)
R ²	0.26	0.28	0.24

t-ratios in parentheses.

Table 4. Comparative Statics

Regression # and format	% change in total GNP from a 1.5° F increase	% change in total GNP from a 3° F increase
OECD		
1 - Log-log, excl. Czech, Hungary, Poland	3.68	7.13
4 - Log-log	3.69	7.15
5 - Log-cubic	4.35	8.26
6 - Linear-cubic	4.18	8.25
Non-OECD		
2 - Log-log, incl. Czech, Hungary, Poland	3.31	6.43
7 - Log-log	3.38	6.55
8 - Log-cubic	3.05	5.85
9 - Linear-cubic	3.65	7.20
ALL		
3 - Log-log	8.71	16.45

Table 5. The Income-Temperature Relationship for Two Colonized Regions

Dependent variable:	#10	#11
ln(GNP) in 1999	Africa	Western Hemisphere
Intercept	18.31 (3.89)	16.06 (5.21)
ln(T)	-2.62 (2.39)	-1.82 (2.49)
Oil per capita	5.12 (2.39)	6.56 (1.83)
Coal per capita	1.36 (2.30)	— ^a
Tourist economy	—	0.61 (1.66)
Number of observations	40	27
R ²	0.36	0.32

t-ratios in parentheses.

^aIn the Western hemisphere, coal per-capita and temperature are highly correlated since the U.S. and Canada have large coal reserves. Thus, results are sensitive to whether coal is included as an explanatory value. Since coal reserves have little explanatory power in the OECD regressions (which include Canada and the U.S.), we exclude them from this regression.

Table 6. The Income-Temperature Relationship for Countries
With and Without Mortality Data

Dependent variable: ln(GNP) in 1999	#12 Countries w/ mortality data	#13 Countries w/ mort. data, non-OECD	#14 Former Soviet Union	#15 Countries w/o mort. data; non-OECD, non-FSB	#16 Countries w/o mort. data; non-OECD
Intercept	14.41 (5.38)	15.76 (3.85)	21.91 (8.22)	12.09 (2.12)	12.19 (6.19)
ln(T)	-0.91 (1.36)	-1.87 (1.96)	-3.56 (5.20)	-1.04 (0.79)	-1.05 (2.23)
Oil per capita	4.14 (1.25)	4.67 (1.02)	12.62 (1.65)	3.04 (3.54)	2.93 (3.81)
Coal per capita	0.17 (0.72)	0.89 (1.13)	-0.68 (1.15)	3.24 (0.86)	0.87 (0.97)
Tourist economy	0.87 (2.04)	1.43 (2.62)	—	1.29 (3.43)	1.18 (3.76)
ln(Mortality)	-0.57 (6.67)	—	—	—	—
N	69	62	15	42	65
R ²	0.63	0.19	0.72	0.37	0.33

t-ratios in parentheses.

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Appendix

Table A1. Summary Statistics

Variable	N	REGRESSION #1 -- OECD (MINUS C, H, P)			
		Mean	Std Dev	Minimum	Maximum
GNP	26	21283.08	6625.38	6126.00	38247.00
TEMP	26	51.0269231	6.7754001	40.1000000	65.3000000
LNGNP	26	9.9054955	0.3865812	8.7202973	10.5518204
LNTEMP	26	3.9238328	0.1334397	3.6913763	4.1789920
PCOIL	26	0.0389305	0.1379393	0	0.7070049
PCCOAL	26	0.2159542	0.6037641	0	3.0062100

Variable	N	REGRESSION #2 -- NON-OECD (PLUS C, H, P)			
		Mean	Std Dev	Minimum	Maximum
GNP	130	4582.87	4754.21	414.0000000	27024.00
TEMP	130	68.4223077	12.5476102	29.7000000	84.6000000
LNGNP	130	7.9905677	0.9531525	6.0258660	10.2044806
LNTEMP	130	4.2063848	0.2053519	3.3911470	4.4379343
PCOIL	130	0.0202246	0.0914472	0	0.8934281
PCCOAL	130	0.0521151	0.1732632	0	1.1922300
TOURIST	130	0.0769231	0.2675002	0	1.0000000

REGRESSION 3 -- ALL					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP	156	7366.24	8054.61	414.0000000	38247.00
TEMP	156	65.5230769	13.4438034	29.7000000	84.6000000
LNGNP	156	8.3097223	1.1370112	6.0258660	10.5518204
LNTEMP	156	4.1592928	0.2216475	3.3911470	4.4379343
FSB	156	0.1666667	0.3738783	0	1.0000000
PCOIL	156	0.0233423	0.1003875	0	0.8934281
PCCOAL	156	0.0794216	0.2958582	0	3.0062100
TOURIST	156	0.0641026	0.2457244	0	1.0000000

REGRESSIONS #4, 5, and 6 -- OECD					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP	29	20138.69	7162.16	6126.00	38247.00
TEMP	29	50.7655172	6.5046289	40.1000000	65.3000000
LNGNP	29	9.8341493	0.4274505	8.7202973	10.5518204
LNTEMP	29	3.9193140	0.1280042	3.6913763	4.1789920
PCOIL	29	0.0350702	0.1308539	0	0.7070049
PCCOAL	29	0.2606372	0.5980493	0	3.0062100

REGRESSIONS #7, 8, and 9 -- NON-OECD					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP	127	4449.69	4721.08	414.0000000	27024.00
TEMP	127	68.8929134	12.3028593	29.7000000	84.6000000
LNGNP	127	7.9616248	0.9448518	6.0258660	10.2044806
LNTEMP	127	4.2140911	0.2012762	3.3911470	4.4379343
PCOIL	127	0.0206643	0.0924834	0	0.8934281
PCCOAL	127	0.0380417	0.1375268	0	1.1922300
TOURIST	127	0.0787402	0.2703994	0	1.0000000

REGRESSION #10 -- AFRICA					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP	40	1881.00	1878.48	414.0000000	8318.00
TEMP	40	73.1375000	7.3473068	60.4000000	84.6000000
LNGNP	40	7.1857985	0.7952770	6.0258660	9.0261771
LNTEMP	40	4.2872917	0.1024562	4.1009891	4.4379343
PCOIL	40	0.0138483	0.0497778	0	0.2988411
PCCOAL	40	0.0360343	0.1894181	0	1.1922300
TOURIST	40	0	0	0	0

REGRESSION #11 -- WESTERN HEMISPHERE					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP	27	6947.52	6547.89	1407.00	30600.00
TEMP	27	68.9518519	11.4986076	41.9000000	82.9000000
LNGNP	27	8.5717558	0.7063202	7.2492151	10.3287553
LNTEMP	27	4.2185874	0.1802967	3.7352858	4.4176351
PCOIL	27	0.0178063	0.0348604	0	0.1397056
TOURIST	27	0.1481481	0.3620140	0	1.0000000

REGRESSION #12 -- COUNTRIES WITH MORTALITY DATA					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP99	69	5819.35	7129.32	414.0000000	30600.00
TEMP	69	70.8681159	10.4002191	41.9000000	84.6000000
PCOIL	69	0.000012744	0.000026814	0	0.000139706
PCCOAL	69	0.0940887	0.4023941	0	3.0062100
MORT	69	237.1634783	457.2956032	8.5500000	2940.00

REGRESSION #13 -- NON-OECD COUNTRIES WITH MORTALITY DATA					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP99	62	4156.40	4907.48	414.0000000	27024.00
TEMP	62	72.9274194	8.6365060	48.6000000	84.6000000
PCOIL	62	0.000010183	0.000025759	0	0.000139706
PCCOAL	62	0.0272485	0.1532813	0	1.1922300
MORT	62	261.4453226	476.6151279	14.9000000	2940.00

REGRESSION #14 -- FORMER SOVIET UNION					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP	15	3943.67	2088.00	981.0000000	7826.00
TEMP	15	49.3800000	7.0889451	39.6000000	61.0000000
LNGNP	15	8.1357715	0.5775287	6.8885725	8.9652068
LNTEMP	15	3.8898978	0.1439172	3.6788291	4.1108739
PCOIL	15	0.0097212	0.0149055	0	0.0414574
PCCOAL	15	0.0915600	0.2004546	0	0.6930000

REGRESSION #15 -- NON-OECD, NON-FSB COUNTRIES WITHOUT MORTALITY DATA					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP99	42	4694.83	5194.48	553.0000000	20586.00
TEMP	42	73.6642857	7.8370857	53.2000000	83.7000000
PCOIL	42	0.000043581	0.000156221	0	0.000893428
PCCOAL	42	0.0113162	0.0383513	0	0.1850000
TOUR	42	0.1428571	0.3541688	0	1.0000000

REGRESSION #16 -- NON-OECD COUNTRIES WITHOUT MORTALITY DATA					
Variable	N	Mean	Std Dev	Minimum	Maximum
GNP99	65	4729.45	4556.68	553.0000000	20586.00
TEMP	65	65.0446154	14.0031585	29.7000000	83.7000000
PCOIL	65	0.000030662	0.000126486	0	0.000893428
PCCOAL	65	0.0483366	0.1209211	0	0.6930000
TOUR	65	0.1076923	0.3124038	0	1.0000000

Table A2. Lists of Countries

OECD (N=29) - #4:

AUSTRALIA	HUNGARY	NORWAY
AUSTRIA	ICELAND	POLAND
BELGIUM	IRELAND	PORTUGAL
CANADA	ITALY	SPAIN
CZECH REPUBLIC	JAPAN	SWEDEN
DENMARK	KOREA.SOUTH	SWITZERLAND
FINLAND	LUXEMBOURG	TURKEY
FRANCE	MEXICO	U.K.
GERMANY	NETHERLANDS	U.S.A.
GREECE	NEW ZEALAND	

Non-OECD (N=127) - #7:

ALBANIA	CONGO (REP.)	INDONESIA
ALGERIA	CONGO (DEM. REP.)	IRAN
ANGOLA	COSTA RICA	ISRAEL
ARGENTINA	COTE D'IVOIRE	JAMAICA
ARMENIA	CROATIA	JORDAN
AZERBAIJAN	CYPRUS	KAZAKHSTAN
BAHAMAS	DOMINICAN REP.	KENYA
BAHRAIN	ECUADOR	KIRIBATI
BANGLADESH	EGYPT	KYRGYZ REPUBLIC
BELARUS	EL SALVADOR	LAO PDR
BELIZE	ERITREA	LATVIA
BENIN	ESTONIA	LEBANON
BHUTAN	ETHIOPIA	LESOTHO
BOLIVIA	FIJI	LITHUANIA
BOTSWANA	FRENCH POLYNESIA	MACEDONIA, FYR
BRAZIL	GABON	MADAGASCAR
BULGARIA	GAMBIA	MALAWI
BURKINA FASO	GEORGIA	MALAYSIA
BURUNDI	GHANA	MALI
CAMBODIA	GRENADA	MALTA
CAMEROON	GUATEMALA	MAURITANIA
CAPE VERDE	GUINEA	MAURITIUS
CENTRAL AFR.R.	GUINEA-BISSAU	MOLDOVA
CHAD	GUYANA	MONGOLIA
CHILE	HAITI	MOROCCO
CHINA	HONDURAS	MOZAMBIQUE
COLOMBIA	HONG KONG, CHINA	NAMIBIA
COMOROS	INDIA	NEPAL

NICARAGUA
NIGER
NIGERIA
PAKISTAN
PANAMA
PAPUA N.GUINEA
PARAGUAY
PERU
PHILIPPINES
ROMANIA
RUSSIA
SAMOA
SAO TOME AND PRIN
SAUDI ARABIA
SENEGAL

SIERRA LEONE
SINGAPORE
SLOVAK REPUBLIC
SLOVENIA
SOLOMON ISLANDS
SOUTH AFRICA
SRI LANKA
SUDAN
SYRIA
TAJIKISTAN
TANZANIA
THAILAND
TOGO
TONGA
TRINIDAD&TOBAGO

TUNISIA
TURKMENISTAN
UGANDA
UKRAINE
UNITED ARAB EMIRA
URUGUAY
UZBEKISTAN
VANUATU
VENEZUELA
VIETNAM
YEMEN
ZAMBIA
ZIMBABWE

Africa (N=40) - #10:

ALGERIA
ANGOLA
BENIN
BOTSWANA
BURKINA FASO
BURUNDI
CAMEROON
CENTRAL AFR.R.
CHAD
CONGO (REP.)
CONGO (DEM.REP.)
COTED'IVOIRE
EGYPT
ERITREA

ETHIOPIA
GABON
GAMBIA
GHANA
GUINEA
GUINEA-BISSAU
KENYA
LESOTHO
MADAGASCAR
MALAWI
MALI
MAURITANIA
MOROCCO
MOZAMBIQUE

NAMIBIA
NIGER
NIGERIA
SENEGAL
SIERRA LEONE
SOUTH AFRICA
SUDAN
TANZANIA
TUNISIA
UGANDA
ZAMBIA
ZIMBABWE

Western Hemisphere (N=27) - #11:

ARGENTINA
BOLIVIA
BRAZIL
CHILE
COLOMBIA
ECUADOR
GUYANA
PARAGUAY
PERU

URUGUAY
VENEZUELA
MEXICO
BELIZE
GUATEMALA
HONDURAS
NICARAGUA
EL SALVADOR
COSTA RICA

PANAMA
CANADA
U.S.A.
BAHAMAS
DOMINICAN REP.
GRENADA
HAITI
JAMAICA
TRINIDAD&TOBAGO

Countries with mortality data (N=69) - #12:

ALGERIA
ANGOLA
ARGENTINA
AUSTRALIA
BAHAMAS
BANGLADESH
BOLIVIA
BRAZIL
BURKINA FASO
CAMEROON
CANADA
CENTRAL AFR.R.
CHAD
CHILE
COLOMBIA
CONGO (DEM. REP.)
CONGO (REP.)
COSTA RICA
COTE D'IVOIRE
DOMINICAN REP.
ECUADOR
EGYPT

EL SALVADOR
ETHIOPIA
FRANCE
GAMBIA
GHANA
GUATEMALA
GUINEA
GUYANA
HAITI
HONDURAS
HONG KONG, CHINA

INDIA
INDONESIA
JAMAICA
KENYA
MADAGASCAR
MALAYSIA
MALI
MALTA
MAURITANIA
MAURITIUS
MEXICO
MOROCCO

NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
PAKISTAN
PANAMA
PARAGUAY
PERU
SENEGAL
SIERRA LEONE
SINGAPORE
SOUTH AFRICA

SRI LANKA
SUDAN
TANZANIA
TOGO
TRINIDAD&TOBAGO
TUNISIA
U.K.
U.S.A.
UGANDA
URUGUAY
VENEZUELA
VIETNAM

Countries w/o mortality data, non-OECD, non-FSB (N=42) - #15:

BAHRAIN
BELIZE
BENIN
BHUTAN
BOTSWANA
BURUNDI
CAMBODIA
CAPE VERDE
CHINA
COMOROS
CYPRUS
ERITREA
FIJI
FRENCH POLYNESIA

GABON
GRENADA
GUINEA-BISSAU
IRAN
ISRAEL
JORDAN
KIRIBATI
LAO PDR
LEBANON
LESOTHO
MALAWI
MOZAMBIQUE
NAMIBIA
NEPAL

PAPUA N.GUINEA
PHILIPPINES
SAMOA
SAO TOME & PRINCIPE
SAUDI ARABIA
SOLOMON ISLANDS
SYRIA
THAILAND
TONGA
UNITED ARAB EMIRATES
VANUATU
YEMEN
ZAMBIA
ZIMBABWE