DOES TEMPERATURE AFFECT LABOR PRODUCTIVITY: CROSS-COUNTRY EVIDENCE

YILDIRIM, Kemal.*
KOYUNCU, Cuneyt.
KOYUNCU, Julide.

Abstract:
This analysis, by using a cross-section data of 111 countries for different samples of 1997-2006 period and Ordinary Least Square (OLS) estimation technique, tests the hypothesis that higher temperature conversely affects labor productivity in a country. The results indicate that there is statistically significant negative relationship between temperature and labor productivity level of a country and this finding remains valid for all samples. Also we identified that temperature level of a country is the second most contributing factor to the explanation of labor productivity level in that particular country. The most contributing factor to labor productivity level is being a high income country.
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1. Introduction

Studies on the economic aspects of temperature/climate in the literature are not abundant and therefore the existing studies explore limited number of issues. Those studies mainly discuss and analyze the association between temperature/climate and economic performance (i.e., per capita income, economic growth, poverty, and economic development).

Mendelsohn et al. (2007) in their study tested whether climate has an impact on per capita rural income by affecting agricultural productivity in the USA and Brazil. They found that climate explains a significant portion of the variation in per capita rural income in both countries. By using a cross-section data of 97 countries, Choiniere and Horowitz (2000) showed that there exists a strong and distinct relationship between income and temperature and a one percent increase in temperature leads to a decline in per capita Gross Domestic Product (GDP) of between 2.0 and 3.5 percent. Horowitz (2001) examined the income-temperature relationship for a cross-section data of 156 countries and concluded that a one percent increase in temperature is associated with a 0.9 percent decrease in per capita income. On the other hand Acemoglu et al. (2001) in their study did not find a statistically significant correlation between temperature and per capita GDP even though the main purpose of their study is to show the effect of institutions on economic performance. It has been shown that countries located in temperate regions are

* Kemal Yildirim, Anadolu University, The Faculty of Economics and Administrative Sciences, Department of Economics, Eskisehir, Turkey.
Cuneyt Koyuncu (the corresponding author), Dumlupinar University, The Faculty of Economics and Administrative Sciences, Department of Economics, Kutahya, Turkey. E-mail: ckoyuncu@dumlupinar.edu.tr or cuneytkoyuncu@yahoo.com
Julide Koyuncu, Bilecik University, The Faculty of Economics and Administrative Sciences, Department of Economics, Bilecik, Turkey.

more developed than those ones located in the tropical regions[1]. In short hotter countries tend to be poorer. Also there are studies analyzing the impact of climate change on economic growth in the literature[2].

In general, the main finding of the aforementioned studies on the impact of temperature on per capita income is that temperature and income move in opposite direction and this correlation is statistically significant. The explanations made on why hotter countries experience lower income are relied on variety reasons. Some of them may be enumerated as; differences in labor and capital productivity in different climates, differences in political and social institutions in terms of their development stages, differences in how quickly capital depreciates in different climates and so on. Temperature may lower the marginal products of physical and human capital and in turn the productivities of labor and capital. Hence, temperature may conversely affect the levels of production of hotter countries through lowering the productivities of labor and capital.

In this study, we would like to explore just labor productivity reducing side of the temperature. In other words we try to identify whether there is statistically significant association between temperature and labor productivity. To our knowledge, this will be the first study addressing to this issue in the literature. If this can be empirically shown then it will be shown and verified that hotter countries, aside from the other reasons, experience lower income through the mechanism of temperature's reducing impact on labor productivity.

In this case we need to explain why and how temperature may affect the labor productivity. Temperature can influence the labor productivity in several ways. First the working premises may not be air conditioned. Presence of excessive heat in working place adversely affects the concentration and efficiency of employees. Second hot temperature may change the mood of individuals. Hot weather might make individuals nervous and lazy. Third it is observed that individuals, in hot weather, experience difficulty in breathing, exhaustion etc. These factors might also influence the labor productivity in a reducing way. Lastly hot weather can help to flourish of epidemic diseases. Thus individuals can get ill in hot weather and in turn this may lower their productivity.

By using a cross-section data of 111 countries for the period of 1997-2006 and for its two sub-sample periods we tested our hypothesis that higher temperature conversely affects labor productivity in a country[3]. Our results indicate that there is statistically significant

[1] For example, see; Theil and Chen (1995) and Ram (1997) for the researches on temperature-development relationship.

[2] For the studies addressing to the issue on association between climate change and economic growth, for instance, see; Masters and McMillan (2001), Fankhauser and Tol (2005), and Lecocq and Shalizi (2007).

[3] The largest sample contains 111 countries and these countries are: Albania, Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Bermuda, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Cambodia, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Georgia, Germany, Greece, Guatemala, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Kazakhstan, South Korea, Kuwait, Kyrgyz Republic, Latvia,

negative relationship between temperature and labor productivity and this finding remains valid in sub-samples.

The remaining part of the paper proceeds as follows: the second part explains the data and methodology; the third part provides and discusses the estimation results; and the last part concludes.

2. Data and Methodology.

The theoretical and empirical researches in the literature have identified numerous variables potentially associated with labor productivity. In this study we use four exogenous variables to analyze how the temperature affects the labor productivity level of a country. These are temperature, openness, capital stock, and a dummy variable representing whether a country is a high income country. The variables used in our analysis were chosen in the light of previous studies found in the literature, the availability of the data and our main hypothesis.

Labor productivity is the ratio of GDP at current USD prices to total employment for a country. Openness is computed by the ratio of imports of goods and services (current USD) plus exports of goods and services (current USD) to GDP (current USD) of the relevant country. Capital stock is the gross capital formation (current USD, in million) of the relevant country. Dummy variable takes the value of 1 if a particular country is a high income country otherwise it takes the value of 0[4]. For each country, we used temperature data from the largest city[5]. We calculated an average annual temperature as the average of twelve average monthly maximum and minimum temperatures of a relevant country.

The data in regard to the temperature come from various sources which are worldweather.org, weatherbase.com, wikipedia.org, and worldclimate.com and it is in terms of Celsius scale. Exports of goods and services, imports of goods and services, GDP, and gross capital formation data are from World Development Indicators (WDI) of the World Bank. Total employment data are gathered from the Conference Board and

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Lithuania, Luxembourg, Macao, Macedonia, Malaysia, Maldives, Malta, Mauritius, Mexico, Moldova, Mongolia, Morocco, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Romania, Russian Federation, Saudi Arabia, Serbia and Montenegro, Seychelles, Singapore, Slovak Republic, Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, St. Lucia, Sweden, Switzerland, Tajikistan, Thailand, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Venezuela, Vietnam.

[4] We used the World Bank's classification in the determination of whether a country is a high income country. In World Bank's classification; economies are divided among income groups according to 2006 gross national income (GNI) per capita, calculated using the World Bank Atlas method. The groups are: low income, $905 or less; lower middle income, $906–3,595; upper middle income, $3,596–11,115; and high income, $11,116 or more.

[5] For the countries having large land areas we used more than one cities temperature data to compute the average annual temperature. These countries and cities are: Australia, Sydney and Melbourne; Brazil, Sao Paulo and Rio de Janeiro; Canada, Toronto and Montreal; China, Beijing and Shanghai; India, Delhi and Mumbai; Pakistan, Lahore and Karachi; United States, New York City, Los Angeles, and Chicago.

Groningen Growth and Development Centre, International Financial Statistics (IFS) of International Monetary Fund (IMF); and World Marketing Data & Statistics of Euromonitor International.

The data utilized in the study are cross-section data of 111 countries. The period under study is between 1997 and 2006. Meanwhile we checked whether the finding for the period of 1997-2006 is valid in the sub-samples for 1997-2001 and 2002-2006 periods.

By utilizing ordinary least square (OLS) estimation method we estimated the following univariate and multivariate models for the entire sample and sub-samples;

$$PROD_i = \beta_1 + \beta_2 TEMP_i + u_i$$
$$PROD_i = \beta_1 + \beta_2 TEMP_i + \beta_3 OPEN_i + \beta_4 CAPSTCK_i + u_i$$
$$PROD_i = \beta_1 + \beta_2 TEMP_i + \beta_3 OPEN_i + \beta_4 CAPSTCK_i + \beta_5 HIGH_i + u_i$$

where *i* subscript stands for the *i*-th country's observation value for the particular variable and u_i is a random error term.

The following further describes the variables and discusses their expected signs.

PROD: labor productivity level in an economy.

TEMP: annual temperature level in a country.

The coefficient on TEMP is expected to be negative since high level of temperature can adversely influence the labor productivity through: reducing concentration and efficiency of employees due to absence of air-conditioning in working places; making employees nervous and lazy by changing their mood; causing to difficulty in breathing, exhaustion, etc.; and helping to flourish of epidemic diseases.

OPEN: openness to trade level of an economy. We expect to have a positive relationship between openness and labor productivity. Increased openness to trade boosts labor productivity in an economy through improving investment in human capital, market size, and diffusion of more efficient production techniques[6].

CAPSTCK: gross capital formation of the relevant country.

CAPSTCK variable is also included as one of the determinants of labor productivity in an economy. This variable is used as a proxy for the investment level in a country. The coefficient on the CAPSTCK is expected to be positive since investment in both human and physical capital improves the labor productivity in an economy.

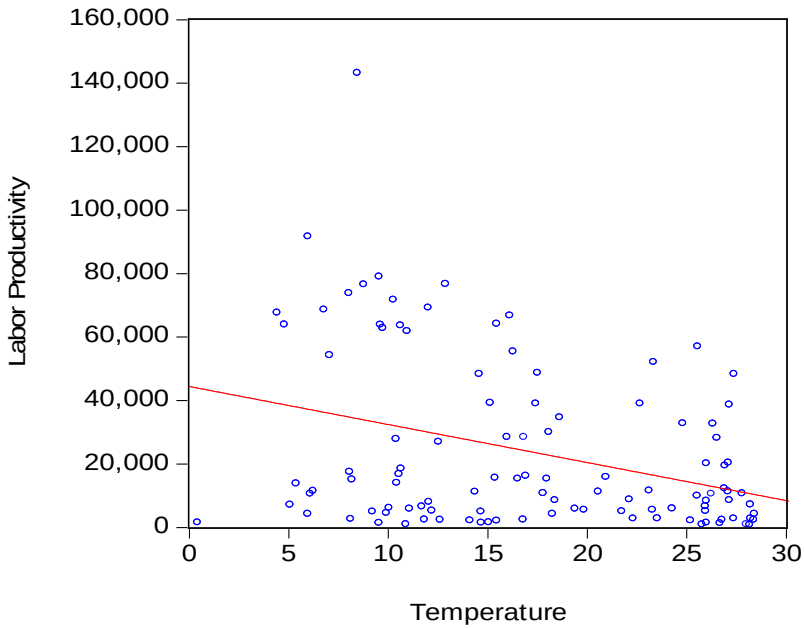
[6] Opening the economy to foreign trade and removing various barriers to trade contribute to productivity of production factors (i.e., human and physical capital) through: enhancing investment in both human and physical capital (Lucas 1988; Romer 1989), the generation and diffusion of more efficient production techniques' know-how (Romer 1986; Krugman 1987; Grossman and Helpman 1991; Coe and Helpman 1993; Dowrick 1994; Miller and Upadhyay 1997) and competition from domestic as well as foreign sources (Madden and Savage 1998; Ahn and Hemmings 2000; Connolly et al. 2004).

Morever, for instance, see: Ades and Glaeser (1999); Frankel and Romer (1999); Alesina et al. (2000); and Alcalá and Ciccone (2001) for empirical evidences suggesting that openness to trade causes productivity.

HIGH: is a dummy variable taking the value of 1 if a country is a high income country, otherwise 0. This dummy variable is used to capture the effect of being a rich country on the labor productivity. One may expect the rich countries to have higher productivity levels because they can afford to employ new technologies and to obtain better life and working conditions (e.g., providing air-conditioned working places). Thus the coefficient on the HIGH variable is hypothesized to be positive.

Before proceeding to the next section, it will be better to discuss the implication of the data for the relationship between temperature and labor productivity. Figure 1 shows the scatter plot for the variables of temperature and labor productivity. The figure also provides a fitted regression line of the data. As can be seen from the figure, there is a negative association between temperature and labor productivity and this implication supports our hypothesis.

Figure 1: The Relationship between Temperature and Labor Productivity (1997-2006).



3. Estimation Results

Univariate and multivariate estimation results for three samples (i.e., for the periods of 1997-2006, 1997-2001, and 2002-2006) are reported in Table 1. In the meantime we also reported univariate and multivariate estimation results for standardized variables in Table 2. The reason behind reporting the estimation results for standardized variables is that using standardized variables in models containing two or more exogenous variables

makes it possible to compare which exogenous variable relatively contributes more to the explanation of the endogenous variable[7].

As shown by results in Table 1, the estimated coefficient of TEMP variable has the expected negative sign and is statistically significant at least at 2% level in all models and across for all time periods. The explanatory power of TEMP is not affected by the inclusion of the new exogenous variables to the models. Hence, this finding suggests a negative relationship between the temperature and labor productivity in a country.

The coefficient of OPEN takes the expected positive sign and, except Model 3 of 2002-2006 period, it remains statistically significant at least at 10% level in all models and across for all time periods. Alike the findings in the literature, we can say that increases in openness to trade are positively associated with the labor productivity in an economy.

Table 1: Univariate and Multivariate OLS Estimation Results.

	1997-2006 Period			1997-2001 Period			2002-2006 Period		
	Model1	*Model2*	*Model3*	*Model1*	*Model2*	*Model3*	*Model1*	*Model2*	*Model3*
CONSTANT	44413.8	27271	13849.3	35333.5	20580.3	9855.7	52424.9	33983.4	18008.3
t-statistics	7.395	4.046	3.136	6.746	3.64	2.658	7.631	4.298	3.454
p-value	0	0.0001	0.002	0	0.0004	0.009	0	0	0.0008
TEMP	-1198.2	-1178.6	-598.9	-825.5	-888	-399.5	-1477.3	-1456.3	-781.5
t-statistics	-3.739	-3.973	-3.085	-2.971	-3.596	-2.46	-4.03	-4.19	-3.418
p-value	0.0003	0.0001	0.002	0.003	0.0005	0.015	0.0001	0.0001	0.0009
OPEN		14280.4	4600.8		13250.7	4182.1		14719.7	4504.9
t-statistics		3.478	1.69		3.629	1.713		3.193	1.472
p-value		0.0007	0.09		0.0004	0.089		0.001	0.143
CAPSTCK		0.043	0.017		0.044	0.02		0.042	0.013
t-statistics		4.188	2.479		4.882	3.348		3.66	1.778
p-value		0.0001	0.014		0.0000	0.001		0.0004	0.078
HIGH			40391.8			33794.3			47141.4
t-statistics			12.437			12.359			12.274
p-value			0.0000			0.0000			0.0000
N	109	108	108	111	108	108	109	107	107
R-Square	0.115	0.284	0.714	0.074	0.301	0.718	0.131	0.27	0.705
D-W Statistics	2.04	2.034	2.213	2.08	2.084	2.221	2.028	2.006	2.207
F-Statistics	13.982	13.795	64.306	8.831	14.97	65.797	16.248	12.751	61.126

As we hypothesized we identified a positive and statistically significant correlation between capital stock (a proxy for investment) and labor productivity across all models

[7] We did not report some statistics (e.g., R-Square, D-W statistics etc.) in Table 2 since those statistics are suitable for the models utilizing standardized variables.

and time periods. This finding remains statistically significant at least at 8% level. Therefore we conclude that increases in investment level in a country lead labor productivity to rise.

Finally we found a highly statistically significant positive association between being a high income country and labor productivity. This result implies that high income countries experience relatively higher labor productivity levels due to the fact that they are able to employ new technologies and to obtain better life and working conditions for employees.

As seen from Table 1, R-square values are getting higher values as we go from a parsimonious model to a larger one. This means that the explanatory power of the models increases as the models get large. Furthermore the high F-statistics values indicate that the models are statistically significant. Meanwhile, the values of D-W statistics imply absence of autocorrelation problem in the models.

Table 2 reports the multivariate estimation results for the standardized variables. As the table shows the coefficients of all exogenous variables are statistically significant and take the expected signs across all Model 2 and Model 3. Besides it can be seen that the significance levels of coefficients, compared to the results in Table 1, are relatively more significant. The most contributing variable to the explanation of labor productivity is HIGH variable in all Model 3. In other words, being a rich country is the main driving force of labor productivity growth.

Table 2: Multivariate OLS Estimation Results for Standardized Variables.

	1997-2006 Period		1997-2001 Period		2002-2006 Period	
	Model2	*Model3*	*Model2*	*Model3*	*Model2*	*Model3*
TEMP	-0.333	-0.229	-0.293	-0.194	-0.357	-0.25
t-statistics	-3.99	-3.31	-3.6	-2.823	-4.206	-3.547
p-value	0.0001	0.001	0.0005	0.005	0.0001	0.0006
OPEN	0.3	0.184	0.306	0.192	0.28	0.164
t-statistics	3.496	2.582	3.649	2.692	3.207	2.261
p-value	0.0007	0.011	0.0004	0.008	0.001	0.025
CAPSTCK	0.361	0.235	0.41	0.288	0.322	0.194
t-statistics	4.209	3.277	4.904	4.023	3.677	2.654
p-value	0.0001	0.001	0.0000	0.0001	0.0004	0.009
HIGH		0.885		0.829		0.902
t-statistics		7.465		6.992		7,388
p-value		0.0000		0.0000		0.0000
N	108	108	108	108	107	107

In all Model 3 but the one for the period of 1997-2001, TEMP variable is the second most contributing variable to the explanation of labor productivity and CAPSTCK is the second most contributing variable to the explanation of labor productivity for the period of 1997-2001. Hence we can state that temperature, in general, is the second main driving force of change in labor productivity level in an economy.

In overall, we conclude that all exogenous variables used in models are taking expected signs and they are statistically significant at conventional significance levels across all models and periods. As we hypothesized in prior, we identified a negative statistically significant relationship between temperature and labor productivity level in an economy in all models and periods. Therefore it can be asserted that higher temperature levels in a country conversely affect the labor productivity levels. We point out that the most contributing factor to the labor productivity level is whether a country is a high income country.

4. Conclusion

In this analysis, using cross-section data of 111 countries for the periods of 1997-2006, 1997-2001, and 2002-2006, we explore whether the temperature has an impact on the labor productivity level of a country. By benefiting from Ordinary Least Square (OLS) estimation technique two separate analyses are conducted. The first analysis using the variables in their original levels just examines if the temperature is significantly associated with the labor productivity in an economy. The second analysis attempts to reveal that which explanatory variable contributes the most to the explanation of labor productivity in a country.

First of all, according to the results from two analyses it should be noted that temperature has a statistically significant negative impact on labor productivity level of a particular country at conventional significance levels across all samples and time periods. The other control variables (i.e.; "OPEN: openness to trade", "CAPSTCK: gross capital formation", and "HIGH: a dummy variable on if a country is a high income country") used in analyses are taking expected signs and are statistically significant at conventional significance levels (except the OPEN variable in the largest model of the first analysis) in all models and time periods for the both analyses.

Regarding to contributions of explanatory variables to labor productivity, the highest contributor to labor productivity level in an economy is HIGH variable. This means that being a high income country is the main driving force of labor productivity growth in that particular country. TEMP variable is the second most contributing variable to the explanation of labor productivity in all Model 3 but the one for the period of 1997-2001 of the second analyses. Thus we say that temperature level, in general, is the second main driving force of labor productivity change in a country.

In sum, in addition to other determinants of labor productivity, temperature level in a country plays an important and significant role in the explanation of variation in labor productivity level of that particular country. Our finding may also shed light on the lasting discussion based on empirical findings in the literature that why climate/temperature conversely affect the per capita income level of a country. According to our finding temperature can be adversely affecting per capita income level of a country via reducing the labor productivity level in that country.

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