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Kontakt/Contact

ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics
Düsternbrooker Weg 120
24105 Kiel (Germany)
E-Mail: [rights\[at\]zbw.eu](mailto:rights[at]zbw.eu)
<https://www.zbw.eu/econis-archiv/>

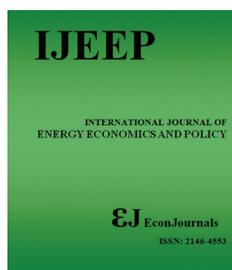
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The Role of Agriculture in Climate Change: A Global Perspective

Jeremiás Máté Balogh*

Corvinus University of Budapest, Hungary. *Email: jeremias.balogh@uni-corvinus.hu

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ABSTRACT

Nowadays, the topic of climate change and its consequences are on the agenda of the everyday life. Due to the greenhouse effect, an effective doubling of Carbon dioxide (CO₂) concentrations is expected by 2030. During the history, the concentration of greenhouse gases (GHGs) in the atmosphere has grown mainly as a result of human activity in the Earth. The anthropogenic CO₂ emission accounts for around three-fourths of global GHG emissions. The development of GHG emissions is extremely associated with global warming. Approximately one-third of the global atmospheric methane emissions derived from agricultural activities. Throughout the agricultural production process, high amounts of GHG emissions are released, which affect negatively the environment and the climate. The intensity of agriculture-related factors of climate change is varying over countries and continents. The objective of the research is to explore the main agricultural-related determinants of climate change focusing on livestock, burning crop residues, rice production, manure management, synthetic fertilizer use along with the geographical and cultural factors of the pollution. The analysis was carried out on a sample representing the world economy.

Keywords: Carbon Dioxide Emission, Agricultural Production, Trade, Language, Geography, World

JEL Classifications: Q10, Q54, Q56

1. INTRODUCTION

In line with the extending industrialization of agriculture, environmental concerns have arisen as a global problem. Carbon dioxide (CO₂) is the main long-lived greenhouse gas (GHG) in the Earth's atmosphere. The increase in CO₂ from 2016 to 2017 was approximately the same as the average growth rate over the last decade (WMO, 2018). An effective doubling of CO₂ concentrations is expected by 2030, resulting in an estimated temperature rise of 1.5-4.5°C.

The atmospheric concentration of GHGs has grown mainly as a result of human activity at global level. Anthropogenic CO₂ emission accounts for around 76% of global GHG emissions (Lanigan, 2017). Furthermore, the growth of GHG emissions is extremely linked to global warming (European Commission, 2018).

Verschuuren (2016) argue that emissions from agriculture have been rising yearly since 1990 at global level, although it shows

important regional differences (decreased in Europe and went up in Asia).

In the last decades, food consumption habits have changed significantly in line with the rapidly growing world population and per capita incomes. The share of the meat consumption in the human diet is also increased, and the globalization has considerably enhanced the trade of the animal feed and processed meat products (Kearney, 2010).

Ritchie (2019) confirmed that actual meat production is nearly five times higher than in the early 1960s, and revealed that high levels of meat consumption can be seen across the West (US, Canada) and in Western Europe (UK).

On one hand, meat production requires significant water, energy consumption and it is responsible for a high quantity of CO₂ and methane emission. On the other hand, meat production is predicted to double for 2050 compared to 1999 (Steinfeld et al.,

2006, p. 20.) stimulating higher agriculture-related environmental pollution.

Paris Agreement signed in 2015 was one of the milestones for mitigating and slow down the effect of global warming. A principal aim of Paris Agreement was to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C and to pursue efforts to limit the temperature increase even further to 1.5°C (UNFCCC, 2018).

By contrast, Agriculture was only specifically mentioned in the various versions of the Negotiating Text for the Paris Agreement on Climate Change, nor in the final text adopted (e.g. Articles 7, 9, 10 and 11 of the Paris Agreement on Climate Change) at COP21 (Verschuuren, 2016).

Within agricultural activities, it is crucial to assess what are the main drivers of GHG emission contributing to climate change.

The objective of the research is to explore the main agriculture-related determinants of climate change (captured by CO₂ emission) focusing on the main sectoral activities as crop production, burning biomass residues, enteric fermentation, manure management, synthetic fertilizers (sub-domain used by FAO) along with the geographical and cultural background of the pollution. The analysis was carried out on a global sample, investigating a long time period, representing the world economy.

The following section outlines the most relevant literature relating to the effects of agriculture on climate change.

2. RELEVANT LITERATURE

According to the literature, agriculture is one of the major contributors to climate change (Cruz, 2016, EPA, 2018). Agriculture was responsible for 7-14% of global CO₂ emissions in 2000-2005 (Grace et al. 2014). Agriculture, forestry, and land use (AFLU) accounted for 24% of 2010 global GHG emissions. GHG emissions from this sector originate mostly from agricultural sub-sectors such as the cultivation of crops, livestock farming, and deforestation (FAO, 2014).

Furthermore, ecosystems are removed from the atmosphere by sequestering carbon in biomass, dead organic matter, and soils offset approximately 20% of CO₂ emissions from AFLU (EPA, 2018).

Agricultural GHG emissions are mainly composed of methane and nitrous oxide. Methane contributes by 16% while nitrous oxide¹ by 6% to the human activity caused global warming (EPA, 2018, IPCC, 2014).

In total, approximately 1/3 of the global atmospheric methane emissions come from crops production, flooded rice fields, animal waste, and biomass burning (Mosier et al. 1998).

1. Methane have 25 times while Nitrous oxide 300 times stronger impact on the climate than CO₂ emission

Due to the growing human population, agricultural productivity has increased globally since the middle of the twentieth century (Burney et al. 2010).

Most of the agricultural CO₂ is derived directly from the activities associated with agricultural production. In the agricultural production process, irrational activities e.g. inappropriate land use, the excessive application of pesticides and chemical fertilizers can lead to the release of high amounts of GHG emissions, which destructively affects the environment (Hongdou et al. 2018, p. 24489).

In agriculture, the application of fertilizers is the highest contributor to nitrous oxide emissions into the atmosphere, while animal waste and livestock production contribute to ammonia emissions (Li 2000; Parton et al. 2015).

Foley et al. (2011) argue that agriculture contributes 30-35% of global GHG emissions by practices associated with tropical deforestation, methane emissions from livestock, emissions from the use of farm machinery and emissions from fertilized soils.

Henders et al. (2015) found that the production of beef, soybeans, palm oil, and wood products in seven countries (Argentina, Bolivia, Brazil, Paraguay, Indonesia, Malaysia, and Papua New Guinea) was responsible for 40% of total tropical deforestation and resulting carbon losses in the period of 2000-2011.

Baccini et al. (2012) suggested that tropical deforestation caused by agricultural purposes is also a major source of GHG emissions.

Appiah et al. (2018) analysed the causal relationship between agricultural production and CO₂ emissions in emerging economies. They found that agricultural GHG emissions continue to rise, and both crop and livestock productions have a negative impact on the environment in BRICS (Brazil, Russia, India, China, and South Africa) countries. They confirmed that increases in economic growth, crop and livestock production encourage environmental pollution.

Appiah et al. (2018) provided a detailed literature review on the nexus of agricultural production energy consumption, economic growth, population and CO₂ emissions.

Agricultural trade also has indirect environmental effects in many developing countries, due to the structural adjustment policies, these regions are devoted to export crops increases. Moreover, many products are flown to Europe from different areas of the World, raising the issue of energy use of transportation (Harris 2004).

Besides, agriculture-related factors of climate change might vary over countries and continents. There is limited literature on the analysis of agricultural-related factors of climate change focusing on geographical distribution.

3. APPLIED METHODOLOGY

In environmental models, dependent variables representing climate change is usually proxied by CO₂ emission as a conversion basis of different GHG.

The applied econometric model investigates the role of agriculture in climate change focusing on the main activities and agricultural trade.

The paper employs the empirical model of Hongdou et al. (2018) for the econometric specification which is based on the theoretical model of Chertow (2001) and York et al. (2003).

The research tests several hypotheses comprising variables related to agricultural activities (livestock, crop production, fertilizer use, burning biomass, manure management), geographical (continents) and cultural variables (the official language) which possibly determine agricultural CO₂ emissions at global level.

The analysed sample covers 159 country data (representing the world economy) for the period of 1961-2017 covering 56 years' period. The study use panel data derived from the Food and Agriculture Organization of the United Nations' statistical database (FAOSTAT, 2018), World Bank (2018a) World Development Indicators, World Bank (2018b), World Integrated Trade Solution Data (WITS).

To date, a few research analysed the environmental aspects of agricultural production (Filiz and Omer, 2012, Baktiari et al. 2015, Asumadu-Sarkodie 2016, Edoja et al. 2016, Balogh and Jámbor 2017, Leitão, 2018, Hongdou et al. 2018), and concluded that agricultural production significantly influences climate change and pollution. FAO (2014) revealed that total GHG emissions from agriculture doubled over 50 years from 2.7 billion tonnes (1961) to more than 5.3 billion tonnes (2011).

Among others, Henders (2015) and Leitão (2018) revealed that agricultural production and land use through intensive agricultural activities and deforestation positively associated with GHG emission. Furthermore, emissions from enteric fermentation constitute 40% of the total GHG emissions, followed by manure left on pasture (16%). The application of synthetic fertilizers accounted for 13% of agricultural emission (FAO, 2014). The fertilizer use and animal waste through ammonia emissions in livestock production are the main contributors to GHG (Li 2000; Parton et al., 2015).

In line with the empirical works, the first hypothesis tests the effect of the livestock sector on CO₂ emission at global level.

H1: The countries with higher livestock have a higher level of CO₂ emissions.

Besides, the production of agricultural crops, flooded rice fields, animal waste, and biomass burning are the main sources of global emissions (Mosier et al. 1998). Furthermore, Muthu (2014) revealed that from vegetables, rice has the biggest carbon footprint in China, followed by wheat and maize sectors. The second hypothesis tests the role of crop production in the world on environmental pollution.

H2: A higher level of rice cultivation stimulates the level of CO₂ emissions in the atmosphere.

Moreover, recent studies shown that burning biomass residues are highly responsible for environmental degradation (Hongdou et al. 2018). In 2011, world total annual emissions from burning biomass were nearly 10% of total emissions from Forestry and Other Land Use Emissions (FOLU), over the period 2001-2011, annual emissions increased by more than 40% (FAO, 2014).

H3: Burning biomass residues heavily encourage the growth of CO₂ emissions.

In 2011, world total annual GHG emissions from manure management were about 7% of total emissions from agriculture, annual emissions increased about 10% over the period 2001-2011 (FAO, 2014). According to Hongdou et al. (2018) Tubiello et al. (2013), manure management as an important agricultural activity stimulates CO₂ emissions.

H4: Manure management has a strong positive impact on stimulating CO₂ emissions.

The population has increased mainly in Asia, Latin America, and Africa, but emissions increase varies widely in the World, depending on geographical location, income, lifestyle, the available energy resources and technologies. Over the last four decades, GHG emissions have risen in every region, although trends in the different geographical regions are diverse. In Asia, GHG emissions grew by 330%, in the Middle East and Africa by 70%, in Latin America by 57% in 2010 (Blanco et al. 2014).

H5: The American and Asian continents via their growing population and expanding agriculture are the major contributors to climate change.

Among others, Leitão (2011), Balogh and Jámbor (2017), Wang, and Ang (2018) revealed that international trade stimulates climate change via the increase of GHG emission.

H6: The expansion of agricultural exports enhances CO₂ emissions.

A linear function can be used to express the relationship between CO₂ emission and emission from agriculture in the world. Following Hongdou et al. (2018), the empirical specifications for the model are calculated as follows:

model 1

$$\ln_{agrCO_{2it}} = \beta_0 + \beta_1 \ln_{biomass_burnt_{it}} + \beta_2 \ln_{livestock_{it}} + \beta_3 \ln_{rica_area} + \beta_4 \ln_{cropland} + \beta_5 \ln_{agr_va_{it}} + \beta_6 \ln_{manure_{it}} + \beta_7 \ln_{agrexport} + \varepsilon_{it} \quad (1)$$

model 2

$$agrCO_{2it} = \beta_0 + \beta_i \ln_{continent_i} \quad (2)$$

model 3

$$agrCO_{2it} = \beta_0 + \beta_i \ln_{language_i} + \varepsilon_{it} \quad (3)$$

where

β_0 denotes the constant

β_i are the estimated panel coefficients

ε_{it} is the error term

i captures country

t represents the time given in year

The detailed description of the employed variables is presented in Table 1.

Agricultural CO₂ emission was used as the proxy for climate change (dependent variable), is derived from FAO (2018) data. Many explanatory variables were considered as determinants of agriculture-related factors of climate change including livestock farming, burning crop residues (biomass burnt), manure management, rice cultivation along with continents, and language clusters dummies.

Panel data includes explanatory variables for country i in year t , ε_{it} is the error term and β_s are the elasticities to be estimated. A panel-data fit generalized least-squares estimator (Greene 2012, Davidson and MacKinnon 1993, Judge et al. 1985) was employed with heteroskedastic and uncorrelated error structure to estimate the econometric model of climate change. The detailed descriptive statistics is found in Appendix.

4. EMPIRICAL RESULTS

Recently, worries about climate change call the attention of decision-makers and global organization to reduce the intensification of environmental pollution and GHG emission.

The United Nations Conference on the Human Environment was the first major international conference on the environment held in Stockholm, in 1972. Under the Stockholm Declaration, governments committed in the preservation and enhancement of the Earth's environment.

The first agreement aiming to mitigate the environmental pollution called the United Nations Framework Convention on Climate Change (UNFCCC), adopted at the Rio Earth Summit in 1992.

A few years later, in 1997, the Kyoto Protocol introduced legally a binding emission reduction targets for developed countries.

In 2015, a new global climate agreement was signed in Paris to reducing poverty, fighting against injustice, and climate change. A principal aim of Paris Agreement was to keep a global temperature rise in this century well below 2°C and to pursue efforts to limit the temperature increase even further to 1.5°C (UNFCCC, 2018).

In the result of the agreement, the Sustainable Development Framework 2030 was established, which set out 17 Sustainable Development Goals, including action on mitigating the effect of climate change.

Regarding the past decades, the total average temperature increased by 0,416°C between 1961 and 2016 (55 years) in the Earth with +0.0237°C annual average change (Figure 1). At the same time, the world total agricultural CO₂ emission increased by 192% compared to 1961 and it is expected to rise by 205% (2030), 221% (2050) in the future (FAO, 2018).

Analysing the total emissions produced in the different agricultural sub-domains, we can observe that CO₂ emission from enteric fermentation (40%), agricultural soils (37%) and manure left on pastures (16%) had the highest share in total agricultural CO₂ emission between 1990 and 2016 (Figure 2).

FAO (2018) statistics suggest that Asian, North and South American countries are the main contributors to agricultural specific CO₂ emission stimulating climate change (Figure 3). In the country ranking, the most populated countries (China, India, Brazil and the USA) were among the most significant contributors in line with EPA (2018).

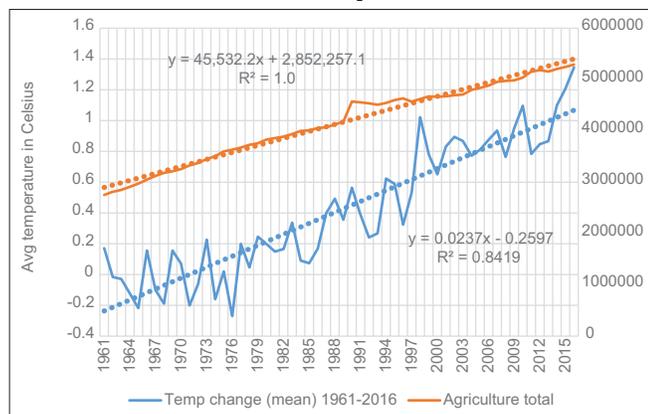
The regression results suggest a positive significant relationship between the livestock sector, the area under rice cultivation, manure management, burning biomass residues, agricultural value-added, the agricultural exports and agricultural CO₂ emissions at global level (Table 2). By contrast, if the share of permanent cropland increase, the CO₂ emissions decrease at world level.

Based on the regression result, the strongest positive environmental impact is discovered between variables capturing burning crop residues and agricultural production (livestock farming and rice cultivation) and CO₂ emission (H1).

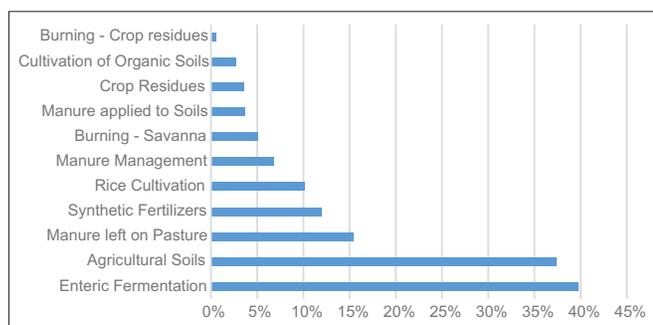
Table 1: Description of variables

Variable	Description	Source
ln_agr CO ₂	Logarithm of agricultural CO ₂ emission in gigagrams	FAO (2018)
ln_biomass_burnt	Biomass burned (dry matter) all crops in tonnes	FAO (2018)
ln_livestock	Logarithm of livestock, major types in livestock units	FAO (2018)
ln_rice	Logarithm of rice, paddy cultivation area harvested in ha	FAO (2018)
Cropland	Permanent cropland (% of land area)	FAO (2018)
agr_va	Agriculture, forestry, and fishing, value added (% of GDP)	World Bank (2018a) WDI
ln_manure	Logarithm of manure treated (N content), all animals, in kg	FAO (2018)
ln_agrexp	Logarithm of agricultural export in quantity	World Bank (2018b) WITS
Continents	=1 if the country belongs to the given continent (Africa, America, Asia, Europe, Pacific), 0 otherwise	CEPII (2018)
Language	=1 if the official language is (English or French or Spanish or Russian or Chinese), 0 otherwise	CEPII (2018)

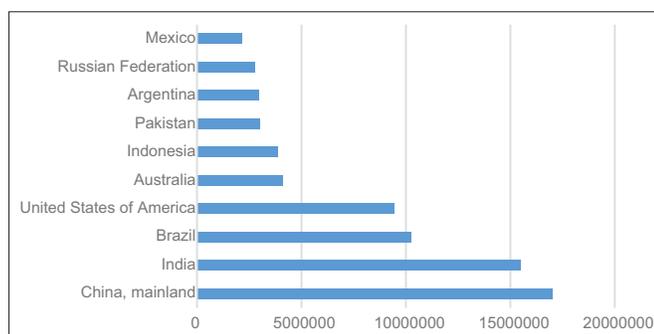
Source: Own composition. WITS: World Integrated Trade Solution

Figure 1: Average temperature change and the evolution of world total agricultural CO₂ emission

Source: FAOSTAT (2018a) Agri-Environmental Indicators

Figure 2: Share of subdomains in total agricultural CO₂ emission, 1990-2016

Source: FAOSTAT (2018b) emissions database

Figure 3: Agriculture total emission in CO₂ equivalent, by top 10 countries, 1990-2016, mean values

Source: FAOSTAT (2018b) emissions database

Moreover, the estimated coefficients of other agricultural variables such as manure management, agricultural value-added highlight the significant role of the agricultural sector in CO₂ emission (H2).

By contrast, increasing the share of cropland and crop production (except rice) might help to reduce the amount of agricultural-related CO₂ emission (negative effect).

From geographic aspects, Asian (1.3), European (1.79) and American (0.735) continents were the highest contributors to

Table 2: Regression results

Variables	(1)	(2)	(3)
	ln_Agri_CO ₂	ln_Agri_CO ₂	ln_Agri_CO ₂
ln_biomass_burnt	0.131*** (0.00313)		
ln_livestock	0.742*** (0.00441)		
ln_rice	0.0461*** (0.000977)		
cropland	-0.00120** (0.000583)		
agr_va	0.00848*** (0.000307)		
ln_manure	0.0479*** (0.00328)		
ln_agrexpport	0.0102*** (0.00159)		
Africa		0.588*** (0.139)	
America		0.735*** (0.139)	
Asia		1.310*** (0.140)	
Europe		1.790*** (0.138)	
Pacific		-2.737*** (0.143)	
English			0.0437** (0.0212)
French			1.243*** (0.0224)
Spanish			2.286*** (0.0192)
Chinese			6.221*** (0.0415)
Russian			4.737*** (0.0468)
Constant	-5.411*** (0.0321)	7.222*** (0.138)	6.862*** (0.00921)
Observations	1,912	8,794	11,452
Number of country	102	158	231

Standard errors in parentheses ***P<0.01, **P<0.05, *P<0.1

climate change (H5). These results are in line with FAO (2014) data: regarding enteric fermentation, Asia and the Americas were the largest emitters (37% and 33% respectively), followed by Africa (14%) and Europe (12%).

Regarding Forestry and Other Land Use Emissions, dominated by the Americas (37%), Africa (28%) and Asia (22%) except for Europe (offsetting about 10% of global FOLU emissions by source).

Based on the estimated coefficients on the language clusters, Chinese and Russian speaking countries are the biggest engines of agriculture-related CO₂ emission at a global comparison, followed by English and Spanish speaking countries.

5. CONCLUSION AND DISCUSSION

The paper investigated the main agricultural-related determinants of climate change focusing on livestock, burning crop residues, rice production, manure management, agricultural value-added

along with geographical and cultural factors of GHG emission. The analysis was conducted on a global sample, representing the world economy.

Based on the regression results a positive significant link is discovered between the agricultural sectors (except crops, excluding rice), agricultural production and CO₂ emissions.

On one hand, research outcomes indicate that effective policy implications are needed to reduce the effect of agricultural-related CO₂ emissions at global level. The reduction in agricultural emissions of GHGs may, in part be attributed to an overall reduction in livestock numbers, more efficient farming practices, the reduced application of fertilisers, as well as better forms of manure management systems (European Commission, 2018).

On the other hand, changing consumption habits, reducing meat consumption (especially beef and pork) in the human diet may diminish the impact of agricultural methane emission on climate change.

A higher share of crop production (excluding rice) might contribute to the reduction of GHG emission.

Agricultural trade is highly responsible for emission-related climate change effects via the transportation of food products. Promoting local agricultural products and short supply chain might help to reduce CO₂ emission along with transportations and trade costs.

Bongiovanni and Lowenberg-DeBoer (2004) suggest that encouraging modern agricultural technologies such as precision agriculture might reduce agriculture-related water, pesticides and fertilizer use.

Finally, Asian countries will be able to moderate their emission by increasing sustainable agricultural practices and shifting to less polluting crop products.

Many of these opportunities, practices, technologies, and systems that are already available and affordable need to be tailored to specific contexts and may require incentives from climate finance to ensure adoption (Verschuuren, 2016).

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APPENDIX

Descriptive statistics					
Variable	Observation	Mean	Standard Deviation	Min	Max
Agri CO ₂	11,89	21934	71919	0	691230
ln_Agri_CO ₂	11,452	7	3	-8	13
ln_biomass_burnt	9,932	11	4	-5	18
ln_livestock	11,342	13	3	4	19
ln_rice	6,454	12	3	1	19
Cropland	9,128	4	8	0	67
ag_va	7,171	18	15	0	94
ln_manure	11,559	16	3	8	23
ln_agrexpport	3,562	20	3	1	35
Continents					
Africa	9,004	0	0	0	1
America	9,004	0	0	0	1
Asia	9,004	0	0	0	1
Europe	9,004	0	0	0	1
Pacific	9,004	0	0	0	1
Official language					
English	12,107	0	0	0	1
French	12,107	0	0	0	1
Spanish	12,107	0	0	0	1
Chinese	12,107	0	0	0	1
Russian	12,107	0	0	0	1

Fisher-type unit-root test based of ADF test								
lag	0				1			
		Statistic	p-value		Statistic	p-value		
Inverse chi-squared (458)	P	758.4099	0.0000	Inverse chi-squared (458)	P	675.2576	0.0000	
Inverse normal	Z	-1.3446	0.0894	Inverse normal	Z	-0.4672	0.3202	
Inverse logit t (1149)	L*	-3.5403	0.0002	Inverse logit t (1139)	L*	-2.4003	0.0083	
Modified inv. chi-squared	Pm	9.9258	0.0000	Modified inv. chi-squared	Pm	7.1784	0.0000	