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Chocolate consumption and Noble laureates

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ABSTRACT

At first glance, the positive correlation of chocolate consumption per capita and the accumulated number of Nobel laureates per capita, as reported by Messerli (2012), seems spurious. The intention of this paper is to check whether this correlation vanishes if relevant covariates and a sophisticated estimation method are employed. A two-stage Heckman selection model is estimated where the stock of Nobel laureates per capita is regressed on chocolate consumption per capita, as well as the number of published scientific papers, R & D expenditures per capita and GDP per capita. In addition, coffee and tobacco consumption per capita are also included. In contrast to the expectation, it is found that a positive correlation between chocolate consumption per capita and the stock of Nobel laureates per capita persists although more recent data and relevant covariates, as well as a sophisticated estimation method are used. In addition, a further negative correlation between coffee consumption per capita and the number of Nobel laureates per capita is detected. Albeit no clear causal relationship between winning a Nobel prize and chocolate or coffee consumption seems to exists, it remains unclear whether the effects are caused by hidden variables or by chance. However, the results are limited due to the lack of individual consumption data.

1. Introduction

In a famous statement, the world-renowned mathematician Paul Erdös once declared: „A mathematician is a device for turning coffee into theorems." Although nobody provided empirical evidence for this tongue-in-cheek statement, another contribution made a fuss in a well-known medical journal. In 2012, Franz Messerli provided evidence for a positive and statistically significant correlation of 0.791 between the number of Nobel laureates per 10 million inhabitants and the chocolate consumption in kilogram per year and capita, including 22 countries (Messerli, 2012). As a preliminary and potential explanation of this correlation, Messerli speculated that "dietary flavonoids" - that are also contained in chocolate - may have improved the cognitive functions of people in those countries. In a literature review on "chocolate and the brain", it is reported that cocoa flavonoids in chocolate "penetrate and accumulate in the brain regions involved in learning and memory" (Sokolov et al., 2013, p. 2445, Abstract). Although there is only a small number of studies with humans, the authors indicate that these studies seem to corroborate the neuroprotective and neurocognitive effects found in animal studies (Sokolov et al., 2013). In a recent mini-review, Valentina Socci et *al.* (2017) presented preliminary evidence for the enhancement of cognitive functions by cocoa flavonoids in humans. However, in the contribution of Franz Messerli the individual chocolate consumption of Nobel prize winners is not included because it is not known.

In this paper, it is investigated whether the correlation found by Messerli (2012) does still persist if the connection between the number of Nobel laureates and chocolate consumption is analyzed with an extended model and a more sophisticated estimation method. Moreover, following Paul Erdös it is asked whether coffee might also be correlated with the number of Nobel laureates. Unexpectedly, the correlation of the number of Nobel laureates and chocolate consumption persists in the new estimations, whereas the consumption of coffee does not correlate with it.

The paper is structured as follows. In Section 2, descriptive statistical results on chocolate consumption, as well as coffee consumption, and the number of Nobel laureates are presented. Section 3 contains the econometric analyses. The empirical results are discussed in Section 4. Section 5 concludes.

2. Chocolate consumption, coffee consumption and Nobel laureates: description

First of all, data on chocolate consumption is not available for all countries of the world. Nonetheless, Chocosuisse (2019) provides data for the consumption of chocolate in kilograms per year and per capita for 27 countries. Table 1 shows the chocolate consumption of the respective countries, as well as the number of Nobel laureates. The data for the latter is taken from Wikipedia's (2019a) list of countries by Nobel laureates up to the year 2018.

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Table 1
Chocolate and coffee consumption (kg per year and capita) and number of Nobel laureates (up to the year 2018) by countries.

Country	Chocolate consumption (kg/year/capita)	Coffee consumption (kg/year/capita)	Number of Nobel laureates (up to the year 2018)
Australia	4.8	2.6	12
Austria	8.5	5.5	21
Belgium	6.4	4.9	10
Brazil	1.2	4.8	0
Canada	3.9	3.4	24
China	0.7	N.N.	9
Croatia	6.6	3.8	3
Denmark	6.9	5.3	14
Estonia	8.8	4.2	0
Finland	7.4	9.6	5
France	3.4	3.2	63
Germany	11.1	5.2	108
Greece	2.5	2.4	2
Hungary	2.9	3.1	13
Ireland	8.8	–	7
Italy	3.1	3.4	20
Japan	1.8	1.5	27
The Netherlands	4.5	6.7	20
Norway	9.2	7.2	13
Poland	2.2	3.1	12
Portugal	3.6	2.6	2
Romania	3.6	1.9	4
Spain	4.5	3.0	8
Sweden	4.4	–	30
Switzerland	10.3	3.9	26
UK	8.1	1.7	133
USA	5.3	3.1	375

Data sources: Chocolate consumption: Chocosuisse (2019); coffee consumption: Caffeineinformer (2019), Number of Nobel laureates: Wikipedia (2019a).

The number of Nobel laureates in Table 1 is 961, out of 1091 Nobel laureates in total; i.e., 88.08% of all Nobel laureates are included in Table 1.

Beside the paper of Messerli (2012), the above quotation of Erdös shows that there might be another positive correlation between a consumption good, in this respect coffee, and creative cognitive achievements. Although the literature on the effects of coffee consumption on labor productivity is inconclusive (Fritz, 2012; Institute for Scientific Information on Coffee, 2017), there could be nevertheless a positive effect on creativity.

To study further both correlations of chocolate and coffee on the number of Nobel laureates, chocolate and coffee consumption are included in multiple regression analyses in the next section.

3. Chocolate consumption, coffee consumption and Nobel laureates: empirical results

3.1. Variables of the empirical investigation

To test whether the correlation between chocolate and coffee consumption with the number of Nobel laureates (per 10 million inhabitants) is robust, multiple regression analysis is applied. Since there is no theory of the creation of Nobel laureates, the following selection of covariates is based on plausibility.

First of all, the number of scientific articles is a candidate as a covariate of the number of Nobel laureates. The reason is that besides the Nobel prizes for Literature and Peace, the remaining Nobel prizes (physiology/medicine, physics, chemistry and economics) are based on articles published in scientific journals.

For the same reason, governmental expenditures for research and development (R & D), in relation to the national GDP, is a second candidate for a plausible covariate. In particular, research in physiology/medicine, physics and chemistry is expensive and state-financed to a very large extent.

The financial capacity of countries depends on their productivity. A measure of productivity is the GDP per capita (measured in purchasing power parities, USD-PPP). This is the third plausible covariate for the estimation.

For a robustness check, two further consumption goods are included: alcohol and tobacco consumption per capita. These goods, too, may have productivity effects that are relevant for the number of laureates.

Table 2 shows the correlations between these covariates.

The sources of the data are:

- Number of Nobel laureates and Nobel laureates per 10 million inhabitants: Wikipedia (2019a). Included are all Nobel laureates until 2018 (inclusively).
- Chocolate consumption in kg per capita: Chocosuisse (2019). Data for the year 2017 (Switzerland: 2018).
- Coffee consumption in kg per capita: Caffeineinformer (2019). Data for the year 2013.
- Alcohol consumption in liter per capita: WHO (2018), data for the year 2016.
- Tobacco consumption, measured as the tobacco smoking prevalence in percent: WHO (2019). Data for the year 2017.
- Number of science articles by country: Wikipedia (2019b). Data for the year 2016.
- R & D expenditures in % of GDP: Wikipedia (2019c). Latest available data.
- GDP per capita in purchasing power parities: World Bank (2019). Data for the year 2017.

3.2. Nobel laureates per capita, chocolate and coffee consumption

In this section, the number of Nobel laureates per 10 million inhabitants is the dependent variable. To test the connection between the relative number of Nobel laureates with chocolate and coffee consumption, data from 70 countries are used. However, only a minority of them has at least one Nobel laureate. This may cause a so-called sample selection bias, because countries with at least one Nobel laureate constitute a nonrandomly selected sample (Heckman, 1979). Since countries with a Nobel laureate differ systematically in a nonrandom way from countries without Nobel laureates, the estimated “random” treatment of chocolate consumption on the number of Nobel laureates would be biased (Heckman, 1979).

An econometric method to account for this restriction is a two-step

Table 2
Correlation between the covariates.

	Chocolate consumption	Coffee consumption	Alcohol consumption	Tobacco consumption	# Science articles	R & D expenditures	GDP per capita
Chocolate consumption	1						
Coffee consumption	0.4536**	1					
Alcohol consumption	0.3085	−0.1435	1				
Tobacco consumption	0.0271	−0.1888	0.4057**	1			
# Science articles	−0.0463	−0.2218	−0.1107	−0.2482	1		
R & D expenditures	0.4626**	0.4033*	0.1069	−0.2517	0.2742	1	
GDP per capita	0.6008***	0.3834*	−0.0841	−0.3483*	0.2941	0.6796***	1

***, **, *: statistically significant at the 1%, 5% and 10% level, respectively.

Heckman estimation (Heckman, 1979). In the first step, it is estimated how a positive number of Nobel laureates (# Nobel laureates > 0, binary variable) is determined by a discriminating variable. This is called the "selection equation". In the case of Nobel laureates, one of the most plausible discriminating variables is the number of scientific articles. Without excellent scientific productivity, it is very unlikely that a country will have any Nobel laureates. This is quasi a "sine qua non"-condition, it decides whether a country may have a Nobel laureate or not, although not all countries with a large number of scientific articles will have one. Since the dependent variable is a binary variable (i.e., either a country has at least one Nobel laureate and gets the variable-value 1, or it has none, with variable-value 0), this "having at least one Nobel laureate" is estimates by a constant of estimation and the number of scientific articles. Since the number of articles is very large, it is divided by 10^5 to get smaller coefficients of estimation. This parsimonious approach to estimate the selection equation is chosen to select all scientifically productive countries for the second step of the estimation procedure.

In the second step, the so-called "response equation" is estimated. Under the condition that the binary variable "having at least one Nobel laureate" is equal to 1 (i.e., the respective country has such a laureate), it is tested whether the *number* of Noble laureates per 10 million inhabitants is connected with the consumption of chocolate. In this way, the selection bias is avoided, as the nonrandom selection of Nobel laureate countries is accounted for by the selection equation.

However, the estimation of the response equation may still suffer from confounding variables that could also have an effect on the relative number of Noble laureates. To control for these possible effects, the number of science articles, R & D expenditures and the GDP per capita are included as independent variables in the estimation of the response equation. Note that the number of science articles is also an important factor concerning the *number* of Noble laureates, in addition to its effect on the likelihood to have at least one Noble laureate. Moreover, also coffee consumption is included, as a reminiscence of the above quotation of Paul Erdös.

The results of both the estimation of the selection equation and the response equation are shown in Table 3. As usual, the selection equation is represented in Table 3 to provide statistical evidence for the effect of the discriminating variable (here: the number of scientific articles) on having a Nobel laureate at all.

Moreover, the results of two different estimations are shown. In the second and third column, the estimation of the effects of chocolate and coffee consumption on the relative number of Nobel laureates is presented, whereas the results of the estimation that includes alcohol and tobacco consumption are given in the fourth and fifth column.

The second and third column of Table 3 indicate by the first step of the Heckman estimation that the number of scientific articles plays a decisive role for having at least one Noble prize winner. Moreover, given that there is at least one Noble laureate, chocolate consumption per capita has a significant positive correlation with the relative number of Noble laureates even when controlling for the covariates. Somewhat surprisingly, coffee consumption is negatively – and statistically significantly – correlated with the relative number of Noble laureates. From the remaining covariates, besides the constant, only the GDP per capita is statistically significant.

Adding alcohol and tobacco consumption as covariates (fourth and fifth column of Table 3) does not change the main results of the preceding estimation. Chocolate consumption remains positive and statistically significantly related with the relative number of Noble laureates, whereas the relation of coffee consumption is still negative. The consumption of alcohol and tobacco is not statistically significantly related to the relative number of Noble laureates.

4. Discussion

The intention of this empirical study was to show that there is no connection between chocolate (as well as coffee, alcohol and tobacco) consumption and the accumulated relative number of Nobel laureates of countries (as in Messerli, 2012), if meaningful covariates are included as explanatory variables. As is well known, correlation is not causation; the former can be "accidental, coincidental or spurious" and then does provide "no causal relationship whatsoever" (Anjum & Mumford, 2018, p. 33).

As the estimations in the previous section demonstrate, it was not possible to reject the hypothesis that chocolate consumption is related to the relative number of Nobel laureates of countries. However, this does certainly not mean that there is a causal relationship between chocolate consumption per capita and the number of Nobel prize winners per capita.

Table 3
Noble laureates and the consumption of chocolate and coffee Main dependent variable: Noble laureates per 10 million inhabitants.

Variable	Coefficient	t-statistic	Coefficient	t-statistic
Response equation: Noble laureates per 10 million inhabitants				
	Chocolate and coffee consumption		Chocolate, coffee, alcohol and tobacco consumption	
Constant	−15.78***	−3.95	−21.49	−1.58
Chocolate consumption (kg per capita and year)	1.43**	2.09	1.32**	2.11
Coffee consumption (kg per capita and year)	−1.50***	−3.46	−1.44**	−2.48
Science articles 2016 (in 10^5)	−1.27	−0.09	−1.35	−0.10
R&D expenditures in % of GDP	1.49	1.09	1.33	0.82
GDP pc PPP 2017 (in 10^4)	4.68***	6.24	5.30***	5.15
Alcohol consumption			0.09	0.14
Tobacco consumption			0.13	0.67
Selection Equation: # Nobel laureates > 0				
Constant	−0.12	−0.81	−0.12	−0.81
Science articles 2016 (in 10^5)	3.99***	3.14	3.99***	3.14
Included observations	70		70	
Mean dependent variable	10.67		10.67	
Standard error regression	3.80		3.68	
Log likelihood	−226.33		−217.37	

***, **, *: statistically significant at the 1%, 5% and 10% level, respectively.

Nevertheless, as indicated by Messerli (2012), the crucial question is whether there are mechanisms that may explain the effect of chocolate (as well as coffee consumption) on Nobel laureates per capita. According to the theory of mechanisms (see, for instance, Anjum & Mumford, 2018, pp. 109–111), the existence of such a mechanism may make the relationship less "accidental, coincidental or spurious" (Anjum & Mumford, 2018, p. 33).

Concerning chocolate, the mechanism might be the effect of Cocoa Flavonoids on cognitive and neuroprotective effects in the human brain (Camandola et al., 2019; Socci et al., 2017; Sokolov et al., 2013). Since Flavonoids are contained in chocolate in not too small quantities, chocolate consumption might provide a certain push effect for cognitive processes in the human brain.

For coffee, too, an enhancement effect of cognitive processes is claimed (Smith, 2005; Nehlig, 2010, 2016). Caffeine, the active ingredient in coffee, is a psychomotor stimulant (Fisone et al., 2004) that affects in particular the dopaminergic system of the human brain (Fredholm et al., 1999; Cauli & Morelli, 2005; Lee & Kim, 2019; Camandola et al., 2019; Stefanello et al., 2019). Among others, the latter has an influence on emotions and perceptions. Dopamine is a neurotransmitter whose deficit may trigger a depression. Recent reviews on the effects of caffeine find enhancing cognitive (and other) effects (McLellan et al., 2016), although coffee is not a "pure cognitive enhancer" (Nehlig, 2010, p. S85). Nevertheless, coffee may intensify concentration and well-being and it may protect against depression (Glade, 2010; Nehlig, 2016). Although coffee breaks have a proper place in the workplace (Institute of Scientific Information on Coffee, 2017), they do not seem to improve productivity (Fritz, 2012).

According to these pharmacological and neurological facts, a mechanism for both chocolate and coffee consumption as boosters of the number of Nobel laureates may be formulated as follows: The higher the consumption of chocolate and coffee, the higher the number of Nobel laureates, because of the effects of flavonoids and caffeine on cognition and the dopaminergic reward system of the human brain. Given this mechanism, chocolate and coffee consumption might be causal for the Nobel effects.

However, these effects are individual effects. No empirical data is available that shows the consumption of chocolate and coffee by Nobel laureates or of persons who are prolific scientific researchers. The data available is aggregate data, and the correlation between chocolate and coffee consumption is on the per capita level (as is the accumulated number of Nobel laureates by country). The conclusion is that the mechanism just described cannot be employed to justify the claim that chocolate or coffee consumption is causal for Nobel prizes.

Furthermore, the correlation between coffee consumption and Nobel laureates per capita is statistically significantly negative. This contradicts the above effects of coffee that should be neutral in the worst case, but not negative. In contrast, there is no obvious reason why the consumption of alcohol and tobacco may have enhancing cognitive effects, as alcohol can lead to dementia, amnestic disorder and psychotic disorders (WHO, 2018, p. 10).

The consequence is that neither the positive correlation of chocolate consumption with the number of Nobel laureates per capita nor the negative correlation of coffee consumption seem to be *causal* relations. Nevertheless, the correlations are persistent even if relevant covariates are included in the estimations and a sophisticated estimation method is employed. The suspicion is that there are hidden variables that are correlated with chocolate and coffee consumption which are the driving forces behind the correlations. However, it can also not be excluded that the existing correlations are accidental, coincidental or spurious.

5. Conclusion

The intention of this contribution was to show that the correlation between chocolate consumption per capita and the number of Nobel laureates per capita (as reported by Messerli, 2012) will vanish if one controls for relevant other variables and if one uses a sophisticated estimation technique.

Surprisingly, the positive correlation between chocolate consumption and Nobel laureates per capita did not vanish, and in addition a further negative correlation between coffee consumption and Nobel laureates per capita was found. These correlations remained statistically significant and stable although a two-step Heckman selection model was employed and it was controlled for the number of scientific papers, R & D expenditures in percent of GDP and GDP per capita. The addition of alcohol consumption and the prevalence of tobacco use did not change the results, too.

Since no mechanism between chocolate and coffee consumption on the one hand and the accumulated stock of Nobel laureates per capita on the other hand could be detected, there is no reason to believe that a causal relationship between the respective variables should exist. Nevertheless, on the individual level such mechanism may exist, but there are no data on the consumption of chocolate and coffee of Nobel laureates on the individual level. Hence, either there are hidden variables that are correlated with chocolate and coffee consumption that cause the correlations or the correlations are accidental, coincidental or spurious. Further research seems to be required to solve this issue.

CRediT authorship contribution statement

Aloys Leo Prinz: is the sole author of the paper.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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