

Does Milk Matter? Genetic Adaptation to Environment: The Effect of Lactase Persistence on Cultural Change

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Introduction

- The role of ecologic environment:
 - Geography (Diamond, 1997)
 - Pathogens load (Murray and Schaller, 2010), epidemics (Clark, 2010)
- Severe environment means more existential hardship for human societies
 - In-group solidarity, collectivism, ‘tight’ culture vs. ‘loose’ culture (Gelfand et al., 2011)
 - ‘Cool-water’ condition (Welzel, 2013; Welzel and Inglehart, 2013)
- Genetic diversity and prosocial behaviour

Genes and Food traditions

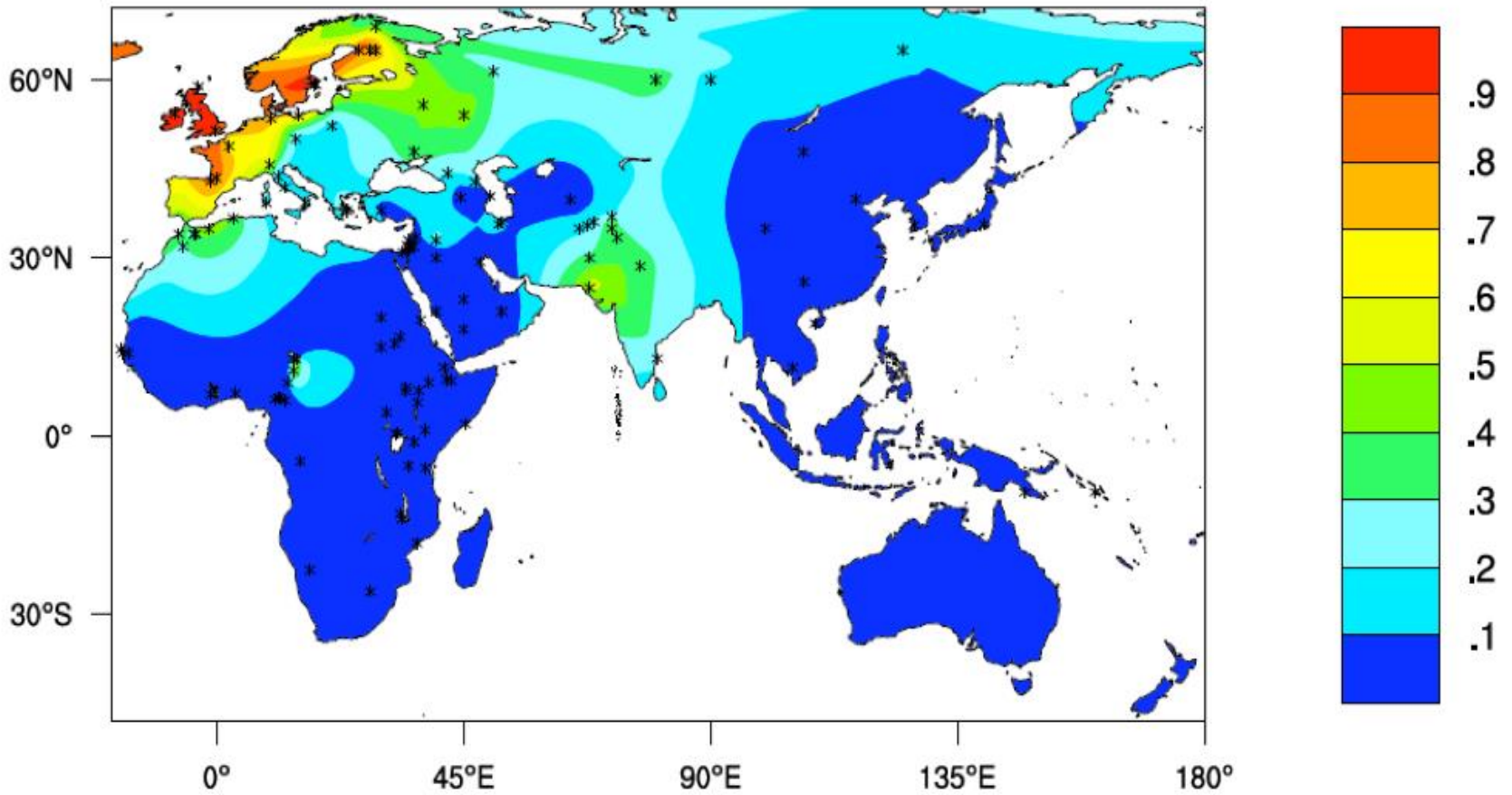
- Diet is an essential part of the environments people are living in
 - Famine, malnutrition and collectivism
 - Climate, geography and food production
- *Diamond*: geographic conditions of Eurasia were the most favorable for earlier sedentary agriculture due to abundance of domesticated cereals and animals. Ever-increasing food production led to earlier population growth and emergence of division of labor, social stratification, urban settlements, and ancient states.
- **Amount** of food is an important factor; is it important **what** people eat?
- Diet is often an outcome to adaptation to geographic environment. For example, 'a thrifty genotype hypothesis'
- Research provides evidence of genetic adaptation to consumption of milk, sugar, mushrooms, starch, meat, beans, alcohol etc. (Borinskaya et al., 2009).

Hypolactasia (lactose intolerance)

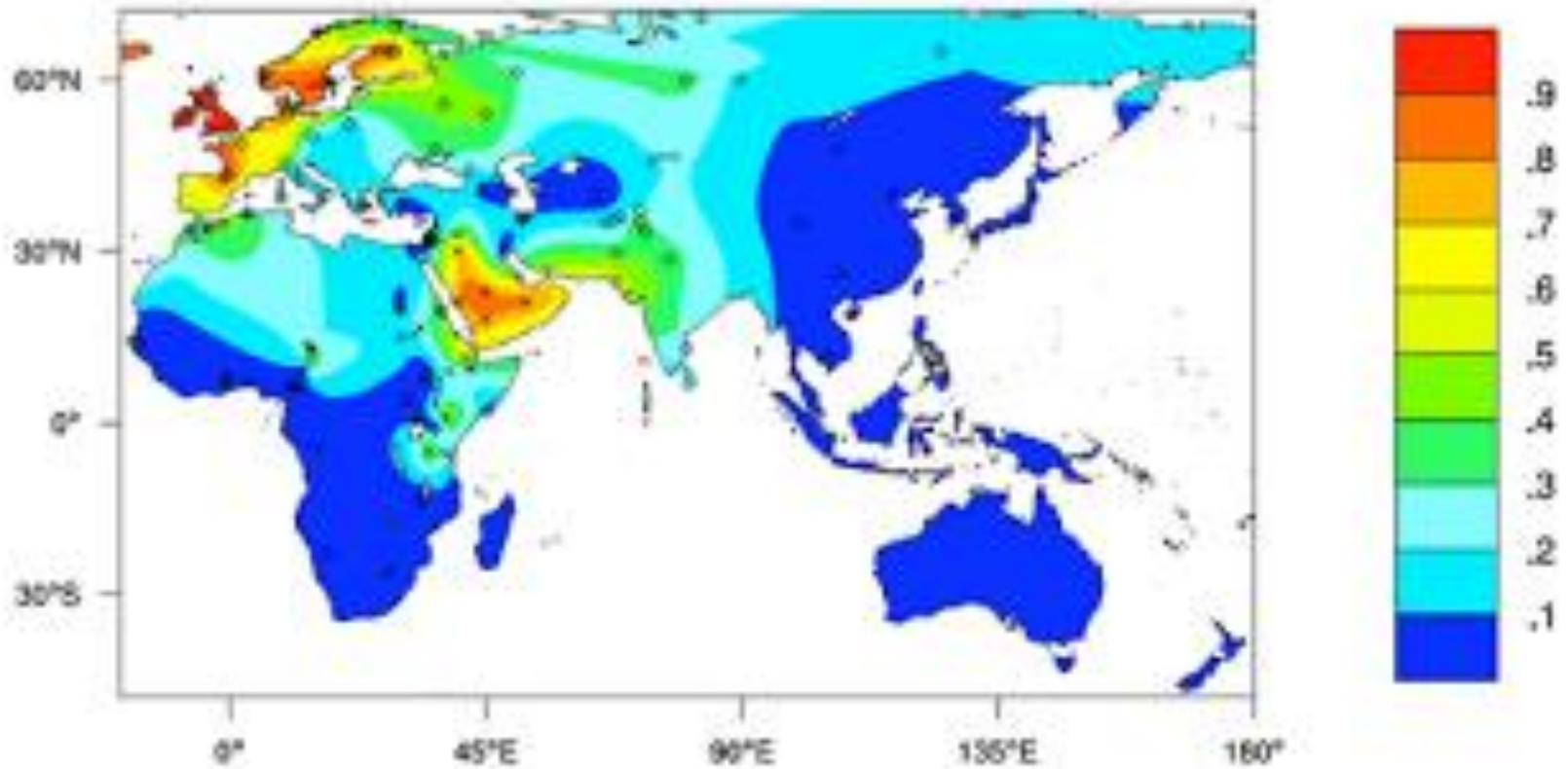
- Lactose intolerance is an inability to digest lactose, a sugar found in milk. Lactose is normally broken down by an enzyme called lactase.
- Lactose intolerance or hypolactasia is associated with gene **LCT**. *LCT** C/T -13910 genotypes are associated with hypolactasia among European populations (f.e., Ingram et al., 2009; Itan et al., 2010). Genotype C/C was reported to be responsible for hypolactasia.
- Frequency of lactose malabsorption (primary hypolactasia) varies dramatically among populations from 2% (Danes) to app. 100% (Chinese, Japanese, Vietnamese) (Kozlov et al., 2005; Borinskaya et al., 2006).
- The lowest frequencies of hypolactasia were found in North-Western Europe, in the areas with the lowest levels of insolation. Low level of insolation means deficit of vitamin D; milk and dairy products are calcium-rich and substitution for vitamin D.

Hypolactasia frequency, % population

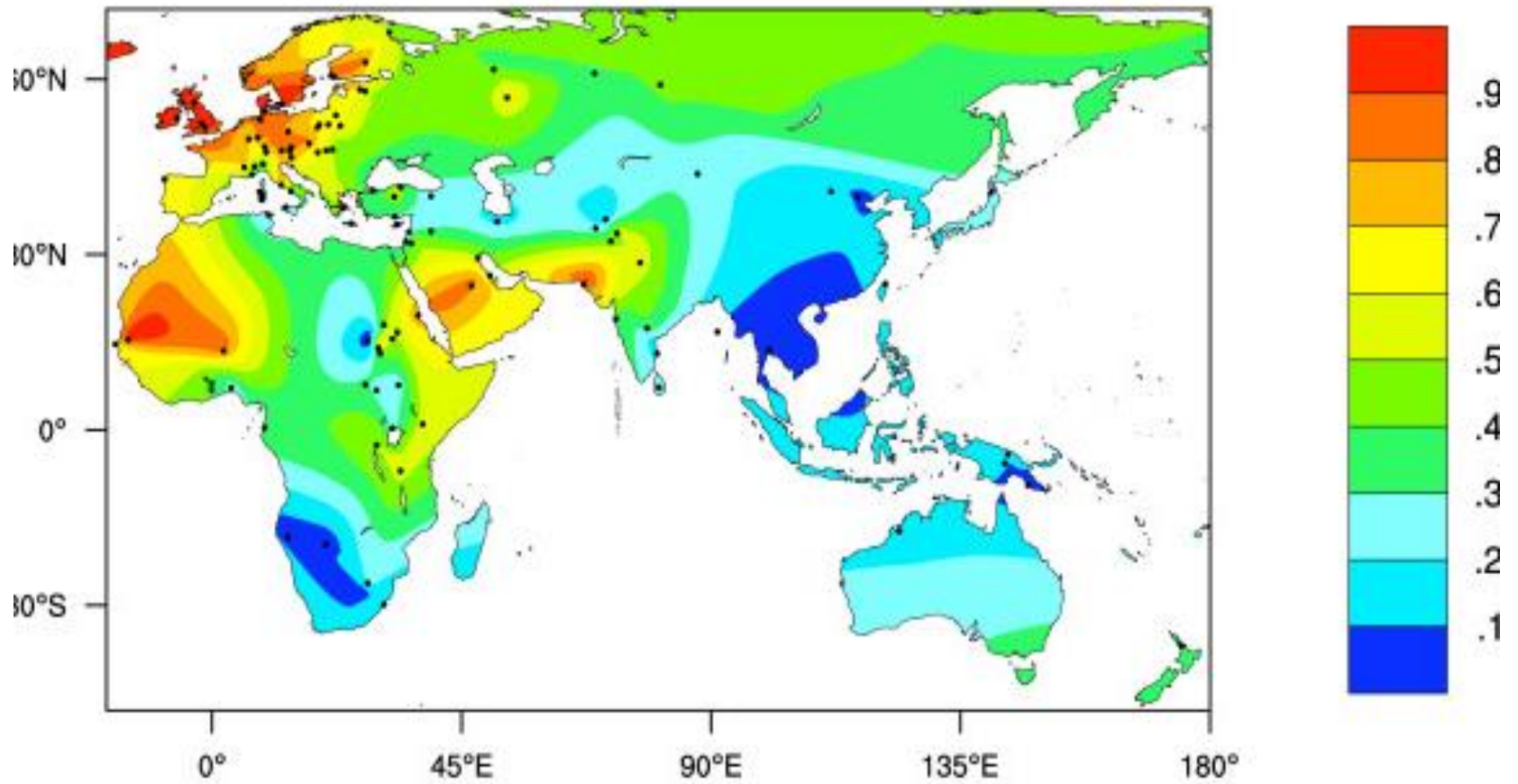
<i>Population</i>	<i>LCT* C/T –13910 genotype frequency</i>	<i>Hypolactasia, share of population</i>
Dutch	0,344	0,02
Danes	0,212	0,03
Swedes	0,069	0,03
Irish	0,148	0,04
Finns	0,173	0,17
Germans	0,437	0,148
Russians	0,740	0,36-0,53
Greeks	0,925	0,45
Italians	0,829	0,71
Koreans	1,000	0,75
Iranians	0,810	0,86
Han	1,000	0,92
Japanese	1,000	1



The worldwide frequency of LCT* C-13910 genotype



Map summarizing all known lactose persistence SNPs and their worldwide frequencies



Old World LP phenotype frequencies

Lactose persistence

- How to explain this variation?
 - The ‘Calcium assimilation’ hypothesis
 - The ‘Arid environment’ hypothesis
 - The ‘Culture-gene coevolution’ hypothesis
 - The ‘Reverse cause’ hypothesis

Lactose tolerance and social effects

Lit review

- 2 papers by Justin Cook (2013)
 - *'The Role of Lactase Persistence in Precolonial Development'*
 - Positive association between frequency of lactose persistence and population density in the Old World in 1500 CE
 - *'Potatoes, Milk, and the Old World Population Boom'*
 - Positive association between interaction effect of frequency of lactose persistence * potato (land suitability) and population growth in 1700-1900

Lactose tolerance and social effects

- Cochrane and Harpending (2009) argue that a high frequency of the European lactose-tolerance mutation (the 13910-T allele) was the driving advantage for *Proto-Indo-European expansion*.
- Reilly (2013) focuses on the relationship between LP and proliferation of *consanguineous marriage pattern* (marriage between second cousins or more closely related individuals) in the Middle East (from 15,3% in Morocco to as high as 65% in Sudan), especially among Bedouins.
- Nowadays, in China and India, despite the absence of a tradition of dairying milk consumption is understood as an essential element of modernization agenda (Wiley, 2011). Milk becomes a synonym for nation's growth and strength: to catch up with the West means to narrow the gap in average height between East and West.

Lactose tolerance and social effects

- Baten and Blum (2014), Koepke and Baten (2008): LP as one of determinants of 'biological standard of living' (average heights)
- Simoons (1973): '*non-milking attitude*' in Asia and Africa. Many people say that they do not know how to milk animals or it is unnatural to manipulate the udder of an animal. Moreover, both Asian and African non-milkers believe that milk is an unclean animal fluid, like urine; non-milkers sometimes protest that milk is a disgusting white substance that both smells and tastes bad.
- Miscellaneous: LP and ovarian cancer incidence; age-specific fertility (Cramer, 1989, 1994).

LP as a nutritional advantage

- Milk is a reserve food resource in times of famine
- About 200 kg of milk - a surplus per cow. A liter of whole milk = app. 720 calories; dairy products from the same amount of milk – only app. 400 calories.
- Such nutritional advantage might have contributed to lower inequality in those societies
- Inequality is understood in a) nutritional (well-fed elites vs. starving lower classes with poor monocereal diets), b) exposure to disease (better diet is associated with better health), c) physical strength (better diet and better health make people stronger) and d) reproductive advantage (better health and lower exposure to disease) terms.
- LP and milk consumption -> *individual autonomy*: Lower classes had more opportunities and resources to protect their rights and property against claims from ruling elites.

Lactase persistence and cultural change

- Can food intolerances affect cultural change?
- *Research question: Does lactase persistence as a product of genetic adaptation to the environment affect cultural change in historical perspective?*
- I expect that LP affects *Emancipative values* via individual autonomy that might be reflected in certain historical demographic and social trends.

Data and methods

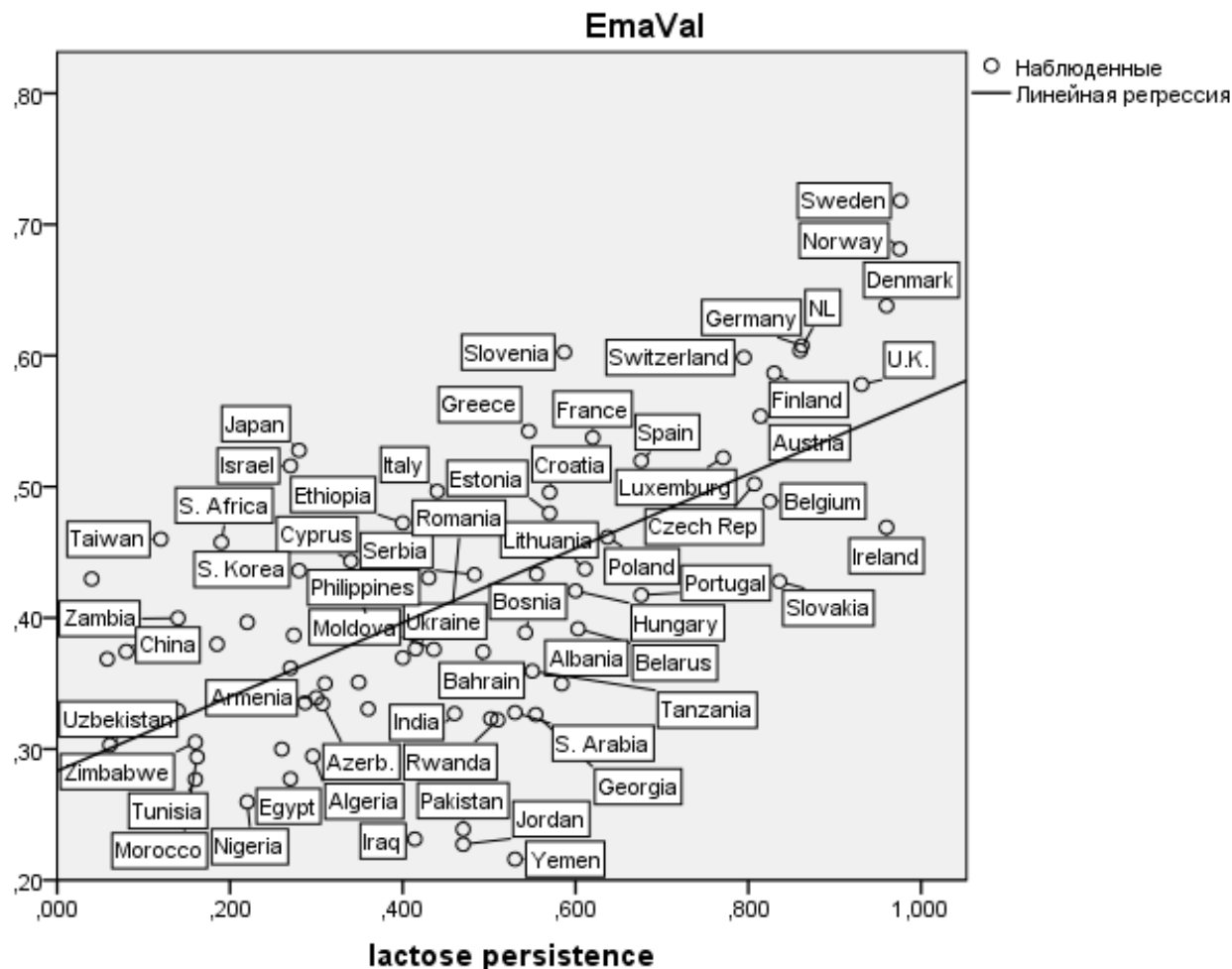
- Conversion of population-based data into country-level data, using ethno-linguistic approximation. 78 populations
- *H*: The higher share of population with *LP* in a given country, the higher is the score for Emancipative Values (and Self-Expression Values).

Variables

- Lactase persistence frequency
- Emancipative values
- Pathogens history
- Income in 1, 1000, 1500 and 1820
- Population density in 1000, 1500 and 1820
- Child mortality in 1800
- Fertility in 1800
- Average height (cm) in 1850
- Serfdom

Sample

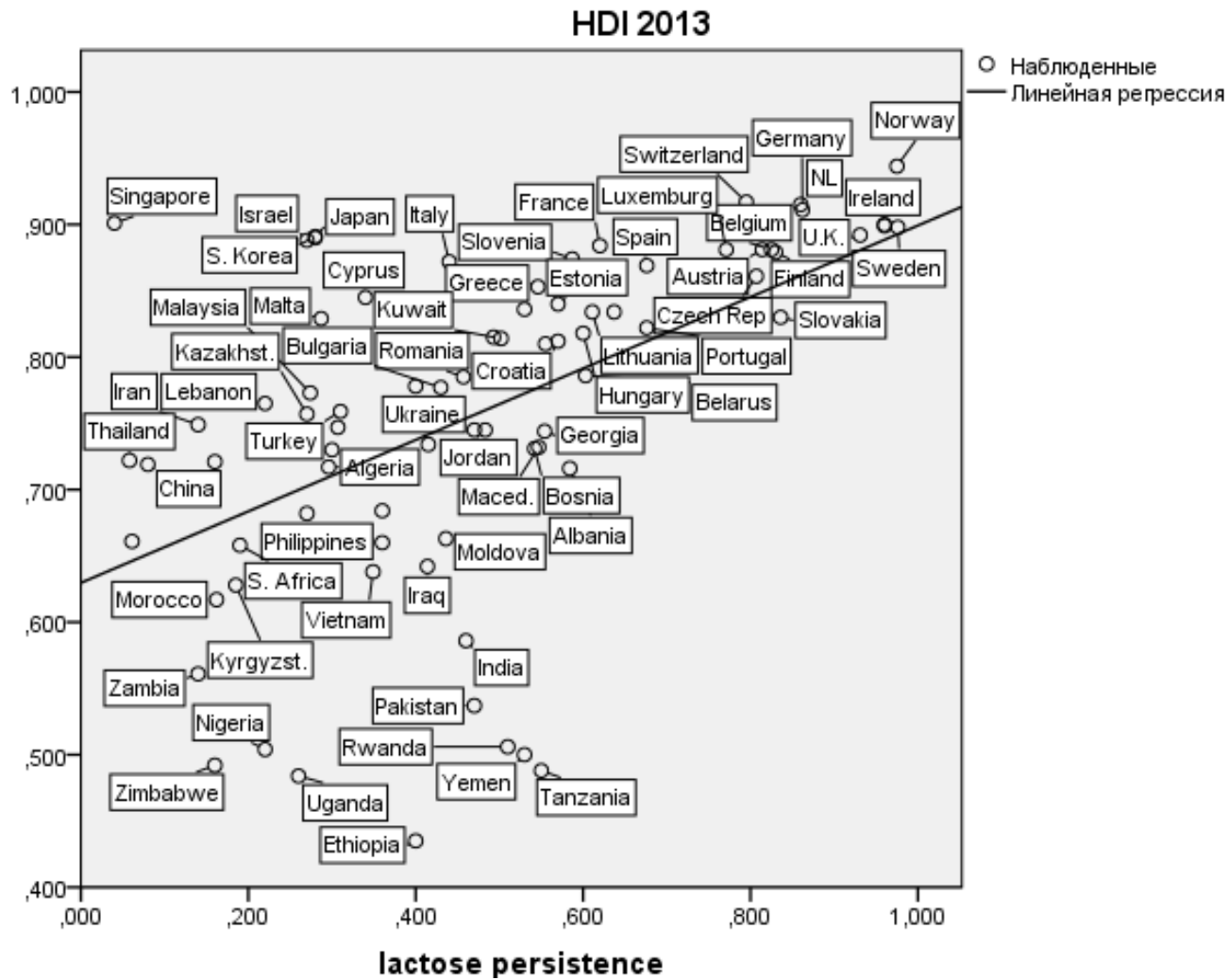
- Cook (2013; 2013a): converts population-based data on lactase persistence (phenotype) into country-based data in three steps.
- Firstly, he takes data for contemporary ethnic composition of existing polities from Alesina (2003). Secondly, he adjusts data on lactose persistence for populations from Ingram (2009) to ethnic groups indicated in Alesina using linguistic approximation. Finally, he calculates country level estimates for lactose persistence for 118 countries.
- I used his matrix to calculate estimates of lactose persistence; in some cases I used Ingram (2009) calculations of country level frequency of milk digestors. My new sample includes 78 cases (Europe – 41, Asia – 25, Africa – 12).



**Correlation between lactose persistence and
Emancipative values**

$r=0,637$, $p=0,000$ $N = 78$

European sample : $r= 0,766$, $p=0,000$



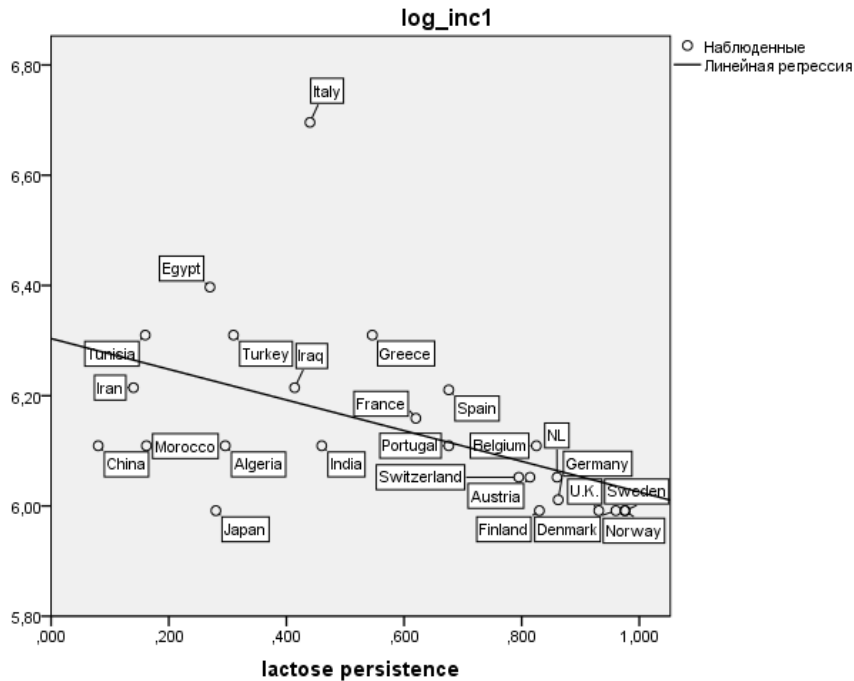
HDI 2013 and LP

$r=0,522$ ($p<0,000$)

LP and income per capita

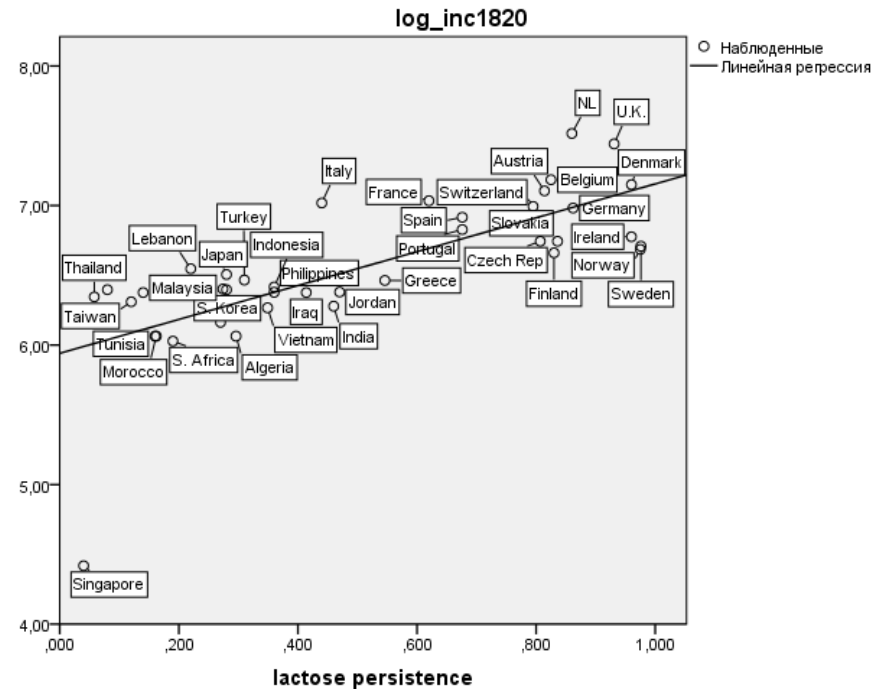
Income in 1 CE

$r = -0,508$, $p = 0,010$, $N = 25$



Income in 1820 CE

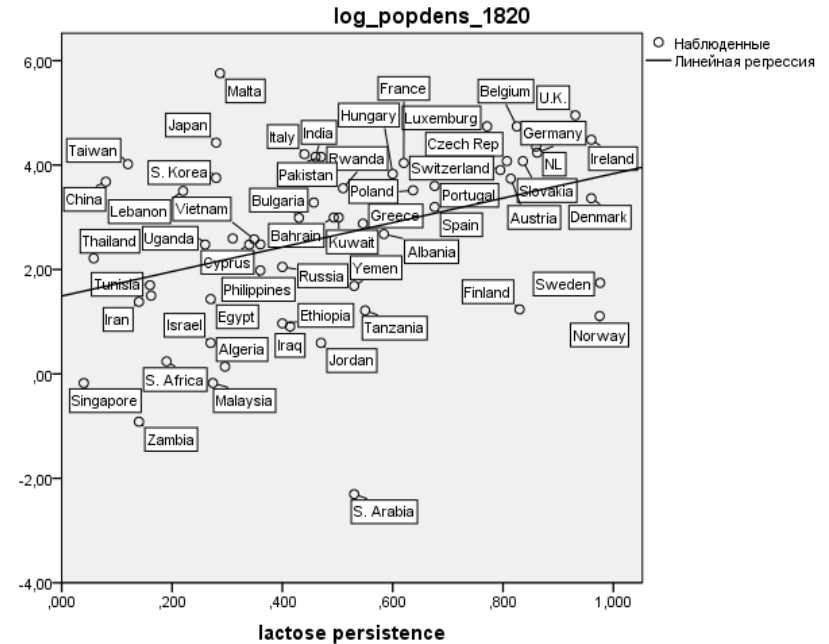
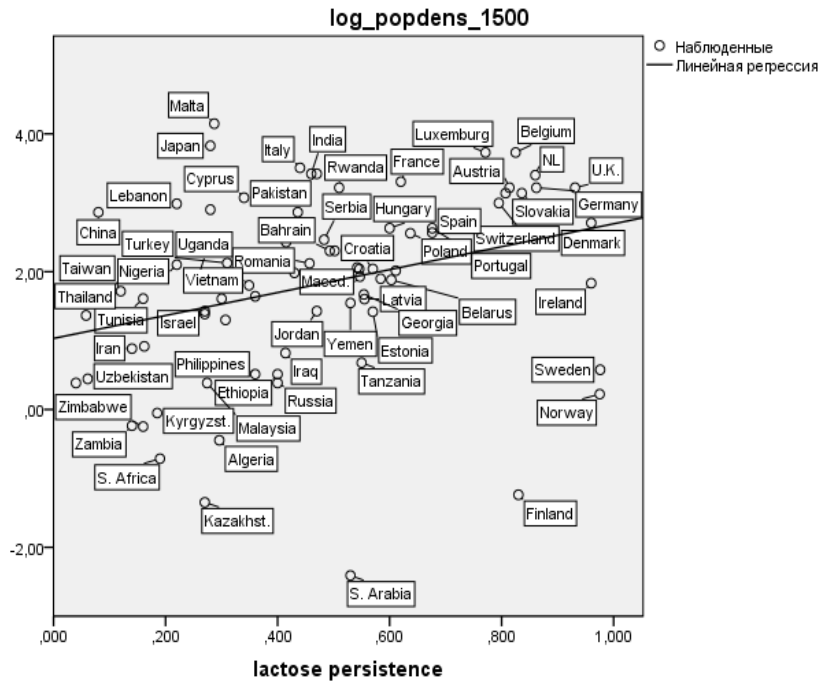
$r = 0,724$, $p = 0,000$, $N = 39$



LP and population density

Pop density in 1500 CE
 $r=0,310$, $p=0,006$, $N=78$

Pop density in 1820 CE
 $r=0,378$, $p=0,003$, $N=58$



LP and demographic trends

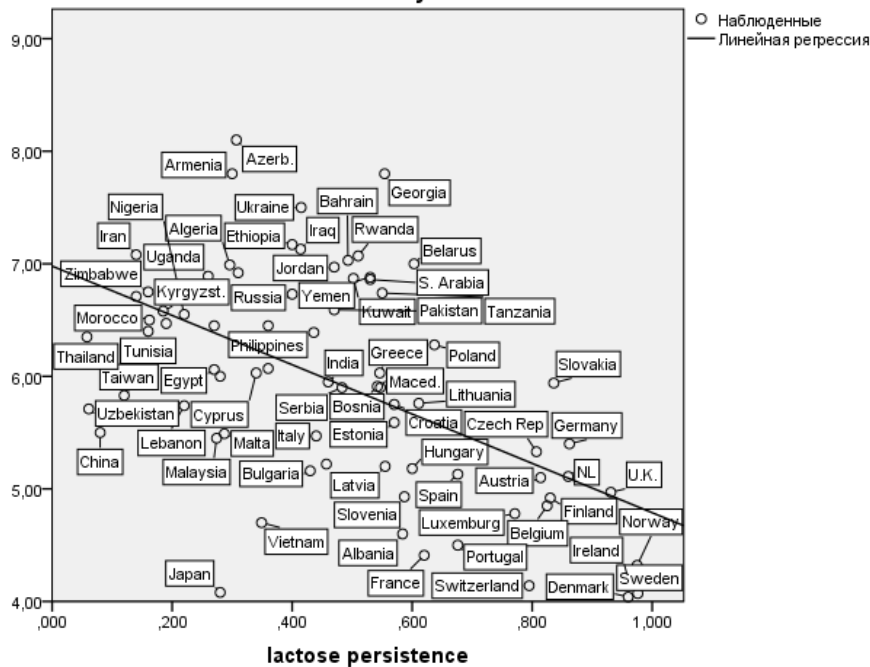
Fertility in 1800 CE

$r=-0,542$, $p=0,000$, $N=76$

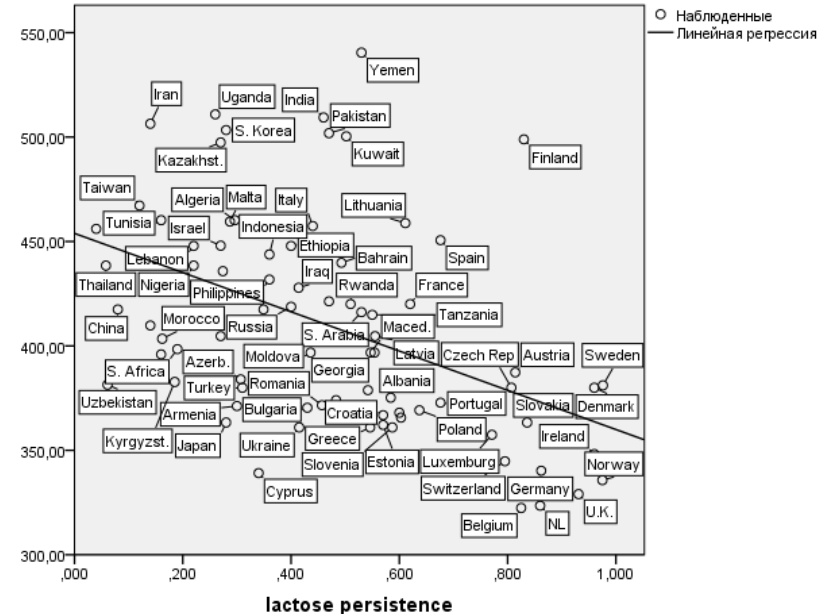
Child mortality in 1800 CE

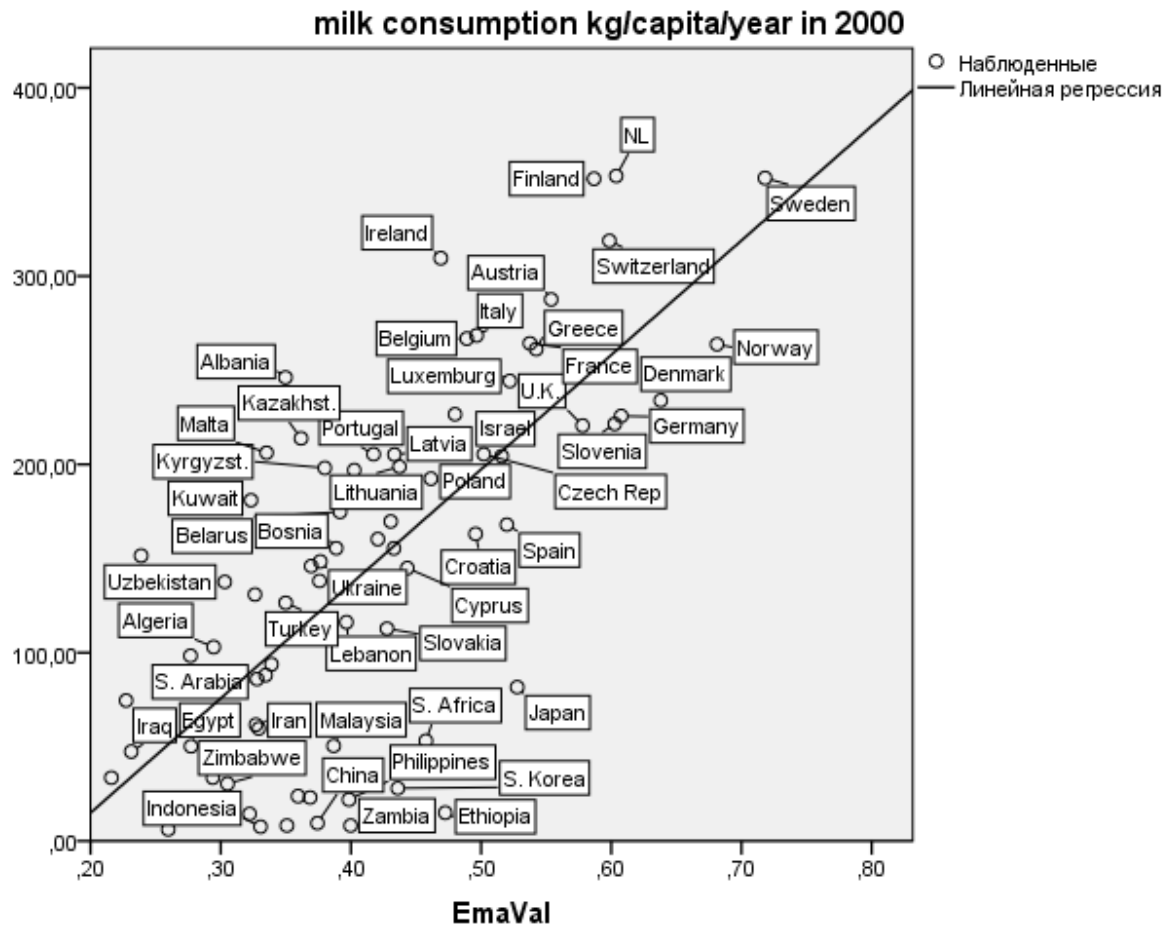
$r=-0,453$, $p=0,000$, $N=78$

fertility rate in 1800



child mortality rate in 1800





Emancipative Values and milk consumption in 2000 CE

$r=0,714, p=0,000, N=74$

LP and serfdom

- Individual autonomy means greater capacity to defend one's rights.
- LP and the emancipation of the serfdom, on European sample (N=33): $r=-0,606$ ($p=0,000$); lactase tolerant societies could enjoy higher degree of freedom

Emancipative Values and LP

	Standardized Beta – coefficients					
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
Lactase persistence	0,637***	0,411***	0,529***	0,420***	0,256**	0,405***
Fertility 1800	-	- 0,478***	-	-	-0,445***	-0,490***
Child mortality 1800	-	-	-0,237**	-	-	-
Pathogens index	-	-	-	-0,338***	-0,270***	-
Heights 1850, in cm	-	-	-	-	-	0,318***
<i>R-square</i>	0,405	0,610	0,450	0,473	0,652	0,771
<i>Adjusted R-square</i>	<i>0,397</i>	<i>0,599</i>	<i>0,435</i>	<i>0,458</i>	<i>0,638</i>	<i>0,748</i>
<i>Observations</i>	<i>78</i>	<i>76</i>	<i>78</i>	<i>78</i>	<i>76</i>	<i>33</i>

Discussion and Further steps

- New causal mechanisms?
- Dairy farming and higher economic autonomy? Direct and/or indirect effects?
- Only milk digestors could use livestock/ cattle in the most efficient way
- W.Europe vs. Near East and Mediterranean grain productivity: 1 – 3 – 9. Collectivism vs. individualism
- Crop growing + cattle husbandry
- Multifunctional use of livestock/ cattle: food, manure and muscle power
- (the late Manchu) China: 7,5 mln non-producers of 400 mln people vs. 6 mln non-peasants of 40 mln people in France
- Europeans commanded more working capital per head, esp. in form of livestock

Discussion and Further steps

Geography and climate: choice of livestock, need for technological innovations (to cultivate non-arable land, to select new breeds [breeding from larger animals]), need for winter fodder. Individual farms had to save more from consumption to survive winter. “An economy based on the savings and resulting investments of individual peasants relying on cattle .. ” (Crotty, 2001). Capital and labor have more power than land?

- Institutions of property rights in capital?
- Any datasets on historical agriculture?

- **THANK YOU!**