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Neuroactive hormones and interpersonal trust: International evidence

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Abstract

Social attachment is vital for human health and welfare. Recent experimental evidence in humans has identified the role of neuroactive hormones, especially the peptide oxytocin, in mediating trusting behaviors. Herein, we test if the endocrinological basis for trust between humans scales up to the country level. Trust pervades nearly every aspect of our daily lives, yet survey data on trust show substantial variation across countries. Using 31 measures of biological, social, and environmental factors associated with hormone levels for a sample of 41 countries, we find that two classes of factors are related to trust: consumption of plant-based estrogens (phytoestrogens), and the presence of environmental conditions that include measures of estrogen-like molecules. Our findings provide preliminary evidence that interpersonal trust at the country level may be related to the intake of neuroactive hormones.

JEL classification: Q57 Bioeconomics

Keywords: Neuroeconomics; Behavioral economics; Trust; Social affiliation; Neuroendocrinology; Oxytocin; Phytoestrogens; Xenoestrogens

1. Introduction

Human beings have evolved to attach socially (Mason and Mendoza, 1998; Carter, 1998; Pedersen, 2004), and attachment is essential for physical and psychological health (Zak et al., 2005b; Harpham et al., 2004; Lindström, 2003). Maternal attachment is necessary for mammalian

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offspring survival, while in some species physiologically regulated pair bonding mechanisms developed to enhance lineage survival. This mammalian attachment system prominently utilizes the neuroactive hormone oxytocin (Carter and Keverne, 2002; Insel and Young, 2001; Carter, 1998; Uvnäs-Moberg, 1998; Carter et al., 1997a,b; Insel, 1997; Pedersen et al., 1992). In this paper we examine whether a societal form of attachment, trusting others, is related to endocrine indicators using cross-country data.

Trust is an important topic to study because it is among the strongest predictors of poverty that economists have found; poor countries are by-and-large low trust countries (Zak and Knack, 2001; Zak, 2006). When trust is low, too few investments that create new businesses and raise employment are undertaken. Investments, which occur over time, require a degree of trust in the party who must fulfill the contract. The general equilibrium model of Zak and Knack (2001) identifies the kinds of institutional environments which produce high trust. High trust occurs when formal institutions efficiently enforce contracts, informal institutions facilitate social relations, per capita incomes are high, and interpersonal heterogeneity is low. Indeed, Zak and Knack (2001) derive a threshold level of trust that is necessary to produce a positive level of income growth—countries below this threshold will not achieve positive income growth. These predictions of this model have been confirmed in extensive empirical tests and have been replicated by other researchers (Zak and Knack, 2001; Beugelsdijk et al., 2004). While some of the factors that produce trust can be modified by policy, especially education levels (Knack and Zak, 2002), it would be useful to know if additional factors affect country-level trust.

The first demonstration of the neuroendocrinological basis for social attachment was the study of maternal behavior in rats by Pedersen and Prange (1979). Subsequent research demonstrated the role of oxytocin and the related neurohormone vasopressin in pair bonding by prairie voles (meadow mice) (Insel and Shapiro, 1992; Carter and Getz, 1993). In addition, oxytocin appears to stimulate, and be stimulated by positive social interactions (Carter, 1998; Panksepp, 1992). Oxytocin "induces a physiological process of 'social motivation' that increases the probability of social interactions" (Carter and Keverne, 2002, p. 328).[1]

Interpersonal trust was among the first issues examined in the new transdisciplinary field of neuroeconomics. Neuroeconomics dates to the late 1990s in the work by Glimcher, McCabe, Smith, Zak and their co-workers (Glimcher, 2003; Camerer et al., 2005; McCabe, 2003; Zak, 2004). Recent neuroeconomics experiments with humans have demonstrated that the receipt of an intentional signal of trust from a stranger is associated with an endogenous release by the brain of oxytocin (Zak et al., 2004, 2005b). Further, elevated oxytocin levels were strongly associated with trustworthy behavior (the reciprocation of trust). In a separate experiment, exogenously manipulating oxytocin levels substantially increased the likelihood that subjects would trust a stranger with money they had earned (Kosfeld et al., 2005). These experiments offer evidence that trust between two individuals is facilitated by oxytocin. This paper examines if *generalized trust* (the likelihood that two randomly chosen individuals will trust each other in a given environment) is also associated with levels of neuroactive hormones at the societal level. That is, we examine if the endocrine–trust relationship scales up to the country level.

Oxytocin is synthesized in the paraventricular nucleus and supraoptic nucleus of the hypothalamus and is released in pulses into the circulatory system. Oxytocin also circulates

[1] Besides parturition and breastfeeding, behaviors that release oxytocin include grooming, massage, immersion in warm water, vibration, electroacupunture, afferent vagal nerve stimulation, feeding, and sexual climax (Carter and Altemus, 1997; Uvnäs-Moberg, 1997, 1998).

centrally, acting as a neuromodulator (Fliers et al., 1986; Tribollet et al., 1992). In humans, areas of the brain associated with memory (the diagonal band of Broca and the nucleus basalis of Meynert) and emotions (the hypothalamus and amygdala) have an accumulation of oxytocin receptors (Insel, 1997), though oxytocin receptors are distributed throughout the brain (Fliers et al., 1986). For example, there are collections of oxytocin receptors in the olfactory bulb and throughout the limbic system (Fernald and White, 2000), regions that process sensory signals from the environment. The distribution of oxytocin receptors in limbic areas suggests that the decision to trust another has an emotional component. This is consistent with debriefings of laboratory subjects who report their decision to trust someone or to be trustworthy is made quickly and with little introspection.

Animal studies indicate that estrogen facilitates oxytocin uptake by facilitating receptor binding and increasing the number of oxytocin receptors (Verbalis, 1999). This may partially explain gender differences in social behaviors and fear avoidance (Carter and Keverne, 2002) as well as in some trust experiments (Zak et al., 2005a,c; Croson and Buchan, 1999). Because oxytocin is highly responsive to estrogen, the latter can serve as an effective proxy for the former.

Reviewing the endocrine-behavioral literature, Carter and Keverne (2002, p. 325) conclude that "... exposure to peptides and steroids may 'retune' the nervous system, altering the thresholds for sociality and aggression". As a result, life experiences and environmental conditions may affect the "set point" of oxytocin. For example, exposure to offspring can chronically raise oxytocin levels (Carter and Keverne, 2002). Other social behaviors may also affect homeostatic oxytocin levels.

The extensive experimental literature showing that oxytocin facilitates pro-social behaviors in mammals suggests that it is a candidate to explain society-wide trust levels separate from institutional and economic factors known to affect trust (Zak and Knack, 2001). Specifically, we hypothesize that human beings living in environments associated with higher levels of oxytocin and/or estrogen are more likely to report that others in their society are trustworthy.

2. Methods

2.1. Data

Since international data on hormones levels are unavailable, we collected data on factors correlated with oxytocin levels. Because oxytocin receptors are upregulated by estrogen, our data collection also included variables correlated with estrogen levels, as well as the presence of estrogen-like molecules in the environment (xenoestrogens). A total of 31 oxytocin-correlate and estrogen-correlate data series were collected for 41 countries (the countries for which data on trust is available). All data series are measured on a per capita basis to correct for differences in population sizes. Data sources and descriptive statistics for all variables are reported in Appendix A.

There are several classes of data that are expected to be correlated with oxytocin and estrogen levels: biological processes that directly impact oxytocin; the frequency of social interactions; and exposure to estrogen-like molecules in the environment. The biological effects measured in this study are sex frequency, the fertility rate, the share of females in the population, and the rate of breastfeeding.[2] Social factors proxying the frequency of social interactions are telephone

[2] Because we are measure factors that may affect chronic oxytocin levels, we include the share of females as a measure of nurturing behaviors that in most societies are performed more by women than men.

usage, population density, home ownership, percentage of rural population, and the proportional representation in each country of six major religious groups (Catholics, Buddhists, Hindus, Jews, Muslims, and Protestants). Religion data is included as religious events are an important venue for social interactions. In addition, previous research has shown that socialization is higher in more ''horizontally organized'' religions (e.g. Protestantism) relative to more ''hierarchically organized'' religions (e.g. Catholicism and Islam) (Putnam, 2000). The biosocial factors in our dataset are expected to raise oxytocin and therefore to be positively related to trust.

The environmental factors that we measure include average ambient temperature, distance from the equator, and several measures of organic and synthetic xenoestrogens. Synthetic estrogens are derived from a number of sources, including pesticides (e.g. herbicides and insecticides such as dichlorodiphenyltrichloroethane (DDT), endosulfan, and other chlorinated hydrocarbons), chemical byproducts associated with plastics (e.g. bisphenol A), pharmaceuticals that enter the ecosystem through waste (e.g. birth control pills, the synthetic estrogen diethylstilbestrol (DES), estrogen antagonists used to treat osteoporosis (raloxifene) and breast cancer (tamoxifen), and the histamine antagonist cimetidine), the breakdown of household products (e.g. detergents and surfactants, especially nonylphenol and octylphenol), and industrial chemicals (e.g. polychlorinated biphenyls (PCBs)). Synthetic xenoestrogen magnitudes are included in our dataset through an index of water pollution, a measure of CO_2 emissions, and three indices of air pollution. We also utilize an index of biodiversity as a general measure of the biological environment. Synthetic xenoestrogens can either mimic the effect of endogenous estrogen (be an agonist) or inhibit the uptake of estrogen (be an antagonist) depending on their action at the receptor site (Safe et al., 1998). As a result, their *a priori* effect on trust is ambiguous.

As for organic estrogens, more than 300 plants have been identified as phytoestrogenic (Tilgner, 1999). Phytoestrogens are found in many foods, principally soy and other legumes, but also peas, rye, rice, beans, beef, dates, and tea. We measure the consumption of 14 types of phytoestrogens by constructing a database of per capita consumption of 28 types of foods (listed in Appendix A) for each country in our sample. Once the types of food consumed per capita are determined, the amounts of various types of phytoestrogens consumed are calculated per person by country using the values in Pillow et al. (1999), Albertazzi et al. (1999), and Mazur (1998).[3] Phytoestrogens have been shown to bind to human estrogen receptors (reviewed in Cassidy and Milligan, 1998; Brzezinski and Debi, 1999) and most are weakly agonistic though some are estrogen antagonists (Mishra et al., 2003). On balance, agonistic effects likely dominate antagonistic ones, and we therefore expect that overall phytoestrogen consumption will be positively related to trust.

The data on trust are obtained from the 1996 World Values Surveys wave (WVS) (Inglehart et al., 2000).[4] The WVS contains data from thousands of respondents from 38 countries, both developed and less developed. Two additional observations (Greece and Luxembourg) are taken from the Eurobarometer survey, while another is from a government-sponsored survey in New Zealand (Gold and Webster, 1990), both of which follow the WVS methodology. The measure we

[3] The primary classes of phytoestrogens (phytoestrogens measured) are isoflavones (daidzein, genistein, formononetin, and biochanin A), coumestans (coumestrol, and total coumestans), sterols (β-sitosterol, campesterol, stigmasterol), flavonols (myricetin, quercetin and kaempferol), and lignans (secoisolariciresinol, and matairesinol).

[4] Or the nearest date to this if 1996 is unavailable.

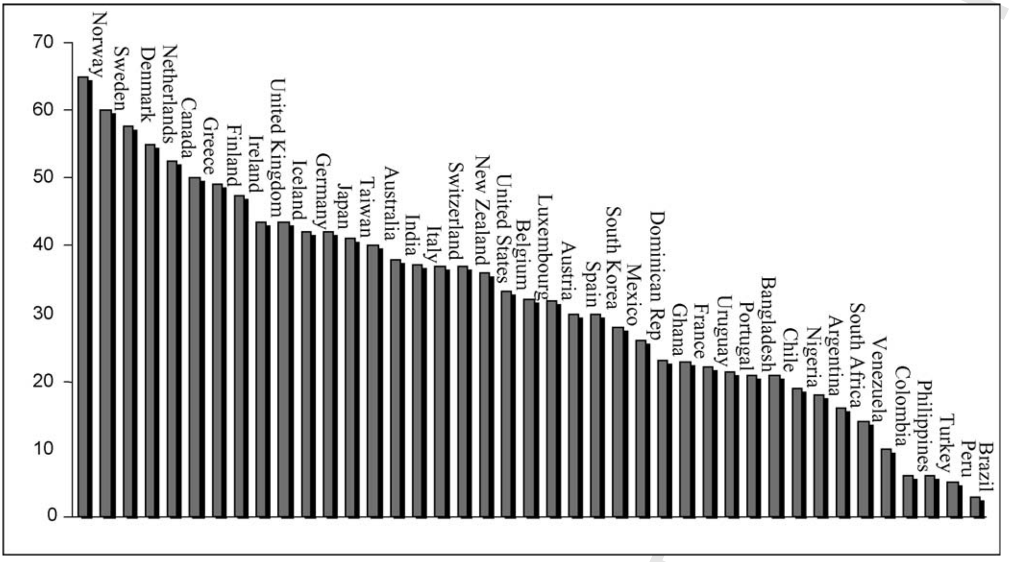

Fig. 1. Trust levels across countries. *Source*: World Values Surveys (Inglehart et al., 2000), Eurobarometer, and Gold and Webster (1990).

use to assess trust is the proportion of those in each country who respond affirmatively to the question: ‘‘Generally speaking, would you say that most people can be trusted, or that you can’t be too careful in dealing with people?’’ This question seeks to capture ‘‘generalized trust’’ which is whether two randomly selected individuals trust each other. The surveys are done in person using the native language, and the questions correspond to impressions of the respondents’ own countries. Fig. 1 presents the trust data used in the analysis. Strikingly, the data vary by an order of magnitude: while only 5% of those surveyed in Peru, and 6% in the Philippines and Turkey say their compatriots are trustworthy, 65% of Norwegians and 60% of Swedes believe this to be so. These data are discussed extensively elsewhere (Zak and Knack, 2001).

The explanatory variables are collected around 1990 to account for possible endogeneity between hormone levels and trusting behavior. That is, hormone levels might be higher because trust itself is high. We mitigate this effect through temporal separation. Lastly, Zak and Knack (2001) show that income strongly affects trust. As a result, any hormonal effect on trust is unreliable unless income is controlled for. We use the price-differences corrected measure of per capita income from Summers and Heston (1991).

2.2. Statistical methods

Because our dataset includes a large number of variables related to hormone levels, there is clearly a degree of freedom problem when doing statistical tests. In addition, while many of the hormone proxies are highly correlated, each only imperfectly reflects oxytocin or estrogen levels. For these reasons, simultaneously testing all variables’ predictive power vis-à-vis trust is infeasible. Yet, examining them one-by-one does not provide sufficiently robust evidence to test our hypothesis.

A more fruitful empirical strategy is to build statistical indicators using entire classes of variables. We employ factor analysis as our variable reduction method (Catell, 1965a,b).

Table 1
Rotated component matrix[a]

	Factors		
	Biosocial[b]	Phyto[c]	Eco-poor
Telephone	−.92		
Breastfeeding	.91		
Air pollution	.88		[−.17][d]
Fertility	.88		[−.11][d]
Distance-equator	−.85		
Sex frequency[e]	−.78		
Female population	−.72		
Hindus[f]	.69		
Ownership	.58		
Protestants[f]	−.47		
Jews[f]	−.24		
Stigmasterol		.96	
Campesterol		.91	
β-Sitosterol		.89	
Quercetin		.87	
Myricentin		.84	
Kaempferol		.83	
Boron		.82	
Courmesterol		.69	
Catholics[f]	[.09][d]		.16
Density		[0.2][d]	−.75
Matairesinol			.75
Muslims[f]	[.40][d]	[.17][d]	−.64
Biochanin			.61
Rural population			−.58
Secoisolariciresinol		[.26][d]	.48
Buddhists[f]	[.30][d]		−.47
Biodiversity			.47
Genistein		[.09][d]	.47
Daidzein		[.09][d]	.47
Water pollution			−.34

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaizer Normalization.
[a] Rotation converged in six iterations.
[b] Four observations were dropped to produce intra-factor consistency.
[c] One outlier was dropped.
[d] For consistency, this loading – rather than the split loading – is deemed primary.
[e] Measured as annual sex frequency.
[f] Measured as percent of the total population.

Factor analysis extracts common variance between sets of variables. The extracted factors are linear combinations of the variables that load on it. That is, a ‘‘factor score’’ substitutes for sets of the original variables, and in this way can identify the principal classes of factors that affect trust. In addition, this method provides a taxonomy of the factors related to trust (Table 1).

We used principal components, the most common form of factor analysis, and Varimax rotation to extract a set of orthogonal factors. After the examination of Catell’s Scree test and the application of Kaiser’s Criterion (Catell, 1965a,b), we retain three factors and call them, *biosocial*, *phyto* and *eco-poor*, respectively. We use Varimax rotation, the default method for rotation, to extract the

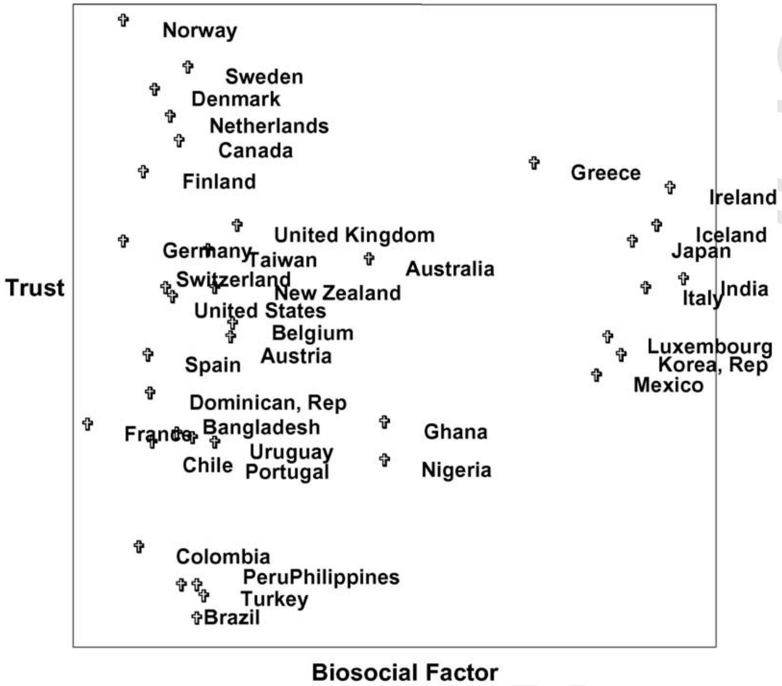

Fig. 2. Scatterplot of trust and the biosocial factor.

variance from the 31 hormone-correlate variables.[5] The second factor was cleaned of three outliers using Cook's distance (Lehman, 1995), and the missing values were replaced using linear interpolation. Details of the factor construction are presented in Appendix A.

3. Results

The statistical procedure that decomposes variables into common factors reflects the broad classes of variables discussed above, but imperfectly so. Indeed, the split loadings on some factors are caused by two aspects of the procedure. First, principal components, based on the extraction of eigenvalues, share the variance in one variable with other variables. Second, by construction, Varimax rotation maximizes the loadings on every factor which exacerbates the tendency to split loadings between factors (Comrey and Lee, 1992). For our analysis, factor assignments were made based on the largest loadings.

The first constructed factor, which we call *biosocial*, includes, in order of the largest factor loadings, telephone penetration, the breastfeeding rate, air pollution, the fertility rate, distance from the equator, sex frequency, and the share of females in the population. Also loading on this factor are the measures of home ownership, and the percent of Hindus, Protestants, and Jews in the population. *Biosocial* accounts for almost 30% of the overall inter-country variance among the 31 hormone-correlate variables included in the analysis. The heterogeneity of the subcomponents of *biosocial* is to be expected as the first factor typically picks up the largest number of variables. Fig. 2

[5] To construct our factors, we use SPSS's factor analysis programs.

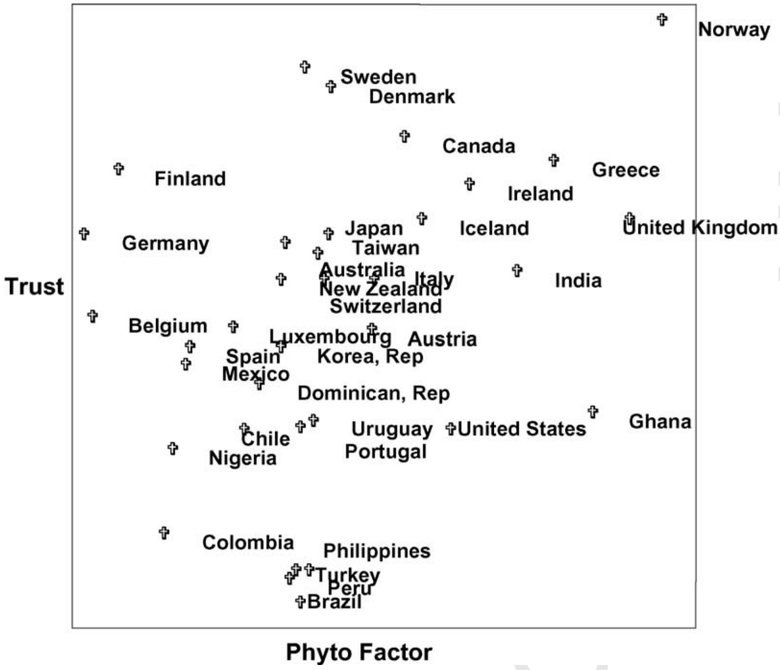

Fig. 3. Scatterplot of trust and the phyto factor.

depicts the scatterplot of *biosocial* and trust. The correlation between biosocial and trust is 0.13 which is not different than zero (*t*-test, $N = 38$, $p = 0.42$, two-tailed).

The second factor, *phyto*, includes eight types of phytoestrogens as primary loadings: stigmasterol, campesterol, β-sitosterol, quercetin, myricentin, kaempferol, boron, coumestrol). This factor explains 20% of the total variation among the 31 hormone-correlate variables. The correlation between *phyto* and trust is 0.34 and is statistically significant (*t*-test, $N = 34$, $p = 0.043$, two-tailed). Fig. 3 plots *phyto* against trust showing the positive relationship.

The third factor, called *eco-poor*, contains the measures of population characteristics, five phytoestrogens, and measures of the quality of the natural environment. The factors in *eco-poor*, in order of the highest loadings are: population density, the phytoestrogen matairesinol, the percentage of Muslims, the phytoestrogen biochanin, the percentage of rural population, the phytoestrogen secoisolariciresinol, the percent of Buddhists, the measure of biodiversity, the phytoestrogens genistein and daidzein, the index of water pollution, and the proportion of Catholics. For consistency, this factor also includes fertility and air pollution as secondary loadings. This factor is heterogeneous, including both ecological conditions as well as factors associated with poverty such as the proportions of religious groups that tend to be poorer as well as a larger rural populations. The name *eco-poor* seeks to denote both these classes of constituents. This factor explains 12% of the overall variance in the hormone-correlate factors. The correlation between *eco-poor* and trust is −0.17, which is not different than zero (*t*-test, $N = 37$, $p = 0.31$, two-tailed). Fig. 4 shows the negative relationship between *eco-poor* and trust.

Table 2 reports a least-squares regression of *biosocial*, *phyto*, and *eco-poor* on trust with per capita income as a covariate control. Since the extracted factors are orthogonal to each other, we are able to regress all three factors on trust simultaneously. The three factors and per capita income explain 70% of the variation in trust.

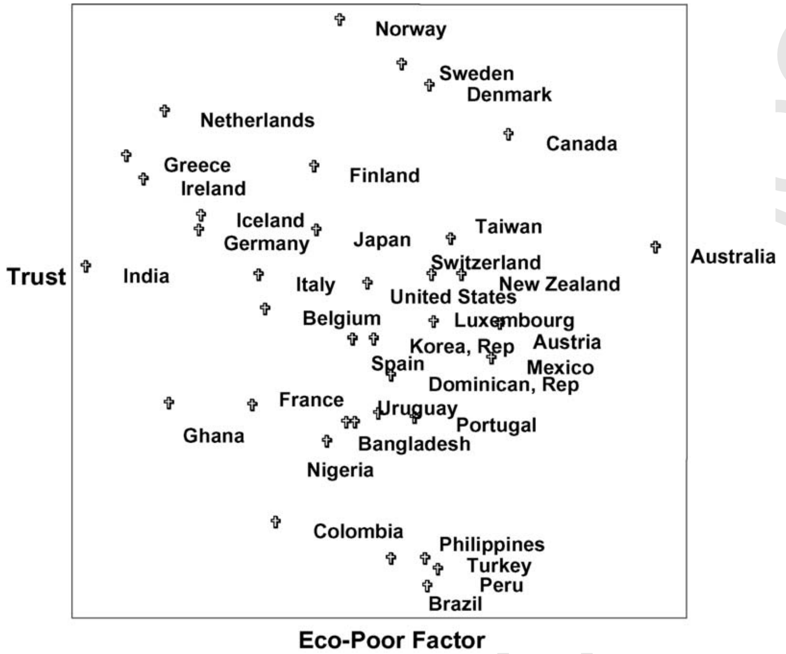

Fig. 4. Scatterplot of trust and the eco-poor Factor.

Table 2
Least-squares regression of the three factors on trust with income as a covariate control

Variables	Biosocial factor	Phyto factor	Eco-poor factor	Per capita income	Intercept	R^2 [*N*]
Trust (S.E.)	.116 (1.645)	**5.830** (2.560)	**−5.306** (2.432)	**2.645** (.356)	12.227 (3.303)	.702 [32]
p-Value	.944	.031	.038	.000	.001	

Although the coefficient estimate for the *biosocial* factor is not statistically significant ($p = 0.94$, *t*-test), its positive relationship to trust is consistent with the effect of childcare and socializing on oxytocin levels. The *phyto* factor is positive and statistically significantly related to trust ($p = 0.031$, *t*-test). This finding indicates that one's diet may affect the quality of social interactions one has. The third factor, *eco-poor*, is statistically significant and is negatively related to trust ($p = 0.038$, *t*-test). The effects of *eco-poor* appear to operate through measures of poverty not captured by income, and by estrogen antagonists, presumably driven by the measures of pollution.

4. Discussion

Our results show that endocrine-correlate measures are related to international levels of generalized trust. The high degree of explained variation is remarkable given the order of magnitude of the variation in trust levels and the moderate sample size. The presumed causal mechanism is either that oxytocin directly raises trust, or does so indirectly by stimulating social interactions which build trust. The insignificance of the *biosocial* factor is to be expected with factor analysis which biases the first factor to include many variables, resulting in high standard errors. In particular, *biosocial* has almost no correlation in the highest trust countries like Norway and Sweden. This occurred because the variables that load on *biosocial* for these countries have little common variance to extract.

An inspection of the scatterplot in Fig. 2 shows the weak correlation between trust and the biosocial factor with the majority of the sample massed about a biosocial value of zero. The *phyto* and *eco-poor* factors are statistically related to trust even after controlling for income. This suggests that the social and biological environments affect average levels of trust in a country.

The evidence does not conclusively demonstrate that neuroactive hormones cause generalized trust, but is consistent with a growing body of experimental evidence showing that trust has a neuroendocrinological basis. The results should be viewed as preliminary since we are extrapolating individual effects from aggregated data. The use of lagged explanatory variables (and the lack of time series data on explanatory variables) do not permit us to determine if the impact of environmental conditions causes chronic or temporary effects on the hormones of interest. We suspect the effects are chronic since food consumption, population subgroups, and geographic factors are relatively constant over time, as are trust levels within countries, but additional research is necessary to demonstrate this. The *eco-poor* factor is more difficult to interpret than *phyto*, as it includes greater heterogeneity in its loadings. Ecological insults such as pollution may raise stress levels (McEwen, 2001), reducing the likelihood of behaving in a trustworthy manner (Heinrichs et al., 2003). Because oxytocin down-regulates stress responses, this finding relates social capital physiologically to health outcomes (Lindström, 2003; Harpham et al., 2004). Further, both the *biosocial* and *eco-poor* factors are associated with cultural practices, so the results may be identifying social factors that indirectly relate culture to trust. Care is therefore required in interpreting our results.

Zak and Knack (2001) and Knack and Zak (2002) identify the role of institutional factors on trust, e.g. measures of corruption, contract enforcement, infrastructure spending, and unbiased application of the law. We therefore regressed the three endocrine-correlate factors *biosocial*, *phyto*, and *eco-poor*, on 10 measures of legal institutions to determine if, for example, the constructed neuroendocrine factors are associated with weak legal systems (Zak and Knack, 2001). None of the 10 institutional measures reach statistical significance for any of the endocrine-correlate factors (*t*-tests; see Table 3). This indicates that endocrine effects may be a new and independent of institutions as explanation for generalized trust, and that these factors affect trust directly, rather than indirectly.

Uvnäs-Moberg (1997, p. 155) writes that "a causal relationship may exist between endogenous oxytocin and personality". If our finding that interpersonal trust has a neuroendocrinological basis is correct, then direct measures of emotions would be expected to be related to trust levels. Cross-country affective measures are difficult to obtain, but the WVS contains data on self-reported happiness and depression. Figs. 5 and 6 plot these affect measures against trust. Happiness is strongly positively correlated with trust (*t*-test, $N = 27$, $r = 0.60$, $p = 0.001$, two-tailed), while depression is significantly negative related to trust (*t*-test, $N = 26$, $r = -0.56$, $p = 0.003$, two-tailed). Indeed, running correlations for all the 80 variables in our initial dataset on trust, we find rates of happiness and depression explain the largest amount of the variation for trust among all the single variables examined. Interestingly, happiness and depression were unable to be included in the constructed factors because the factor matrix was noninvertible, although happiness and depression are not themselves significantly correlated (*t*-test, $r = -0.29$, $N = 26$, $p = 0.15$, two-tailed). The inability to include happiness and depression in the constructed

Table 3
Hormone-correlate factors and institutions

Variables	Biosocial factor	Phyto factor	Eco-poor factor	Per capita income	Intercept	R^2 [N]
Corruption index (S.E.)	−0.12 (.14)	.25 (.22)	−.149 (.21)	**0.21**[a] (.31)	2.52 (.28)	.65 [32]
p-Value	.39	.25	.48	.00	.00	
Rule of law (S.E.)	0.02 (.12)	.11 (.18)	−.22 (.17)	**0.23** (.02)	3.01 (.24)	.74 [32]
p-Value	.86	.55	.21	.00	.000	
Bureaucracy (S.E.)	0.02 (.10)	.13 (.16)	−.19 (.16)	**0.22** (.02)	2.98 (.21)	.77 [32]
p-Value	.84	.42	.24	.00	.00	
Ethnicity (S.E.)	.16 (.19)	−.37 (.30)	−.13 (.29)	**0.09** (.04)	4.09 (.39)	.17 [32]
p-Value	.41	.24	.64	.04	.00	
Repudiation of contracts (S.E.)	.171 (.14)	−0.01 (.22)	−0.01 (.21)	**0.14** (.03)	7.99 (.28)	.47 [32]
p-Value	.24	.99	.96	.00	.00	
Expropriation risk (S.E.)	0.02 (.12)	.13 (.18)	0.02 (.18)	**0.07** (.02)	9.22 (.24)	.69 [30]
p-Value	.85	.49	.89	.019	.00	
Bureaucratic delays (S.E.)	−0.05 (.06)	0.02 (.09)	−0.01 (.08)	**0.10** (.01)	1.28 (.13)	.72 [26]
p-Value	.44	.81	.89	.00	.00	
Contract enforcement (S.E.)	−0.04 (.06)	0.01 (.10)	**−0.18** (.09)	**0.13** (.01)	1.52 (.13)	.80 [26]
p-Value	.47	.91	.05	.00	.00	
Nationalization risk (S.E.)	−0.02 (.09)	−0.07 (.14)	−.113 (.12)	**0.08** (.02)	1.98 (.19)	.42 [26]
p-Value	.83	.60	.38	.00	.00	
Infrastructure quality (S.E.)	0.002 (.07)	0.06 (.11)	−0.09 (.10)	**0.12** (.01)	1.48 (.16)	.74 [26]
p-Value	.97	.55	.37	.00	.00	

[a] Significant slope coefficients are emphasized in bold.

factors occurred because of the high and statistically significant correlation between happiness and ambient temperature (−), distance to the equator (+), telephone usage (+), and sexual frequency (+). Depression is statistically strongly correlated with breastfeeding rates (+), home ownership (+), distance to the equator (−), and telephone use (−). We leave a full understanding of these relationships for further research, but it suggests that trust and happiness are positively associated.

Experimental research with humans reveals a surprising amount of interpersonal cooperation (Smith, 1998; Berg et al., 1995). There is accumulating evidence that trusting behaviors can be partially explained by the presence of neuroactive hormones (Zak et al., 2004, 2005a,b; Kosfeld et al., 2005). Trust is important at the societal level because it facilitates transactions and thereby stimulates economic growth. We have shown here that trust and measures of estrogenic hormones are directly associated with each other. We have also identified a positive relationship between self-reported happiness and trust. While increasing incomes are only weakly associated with increased happiness (Easterlin, 2003), the neuroscientific evidence suggests that there are bidirectional feedbacks between happiness and trust (Zak et al., 2005b; Febo et al., 2005).

The results here indicate that particular environmental conditions in some nations may be conducive to higher trust levels. Specifically, nations that have higher incomes, cleaner environments, and that consume more food containing phytoestrogens are expected to have higher levels of generalized trust. This information can be directly used by policy-makers

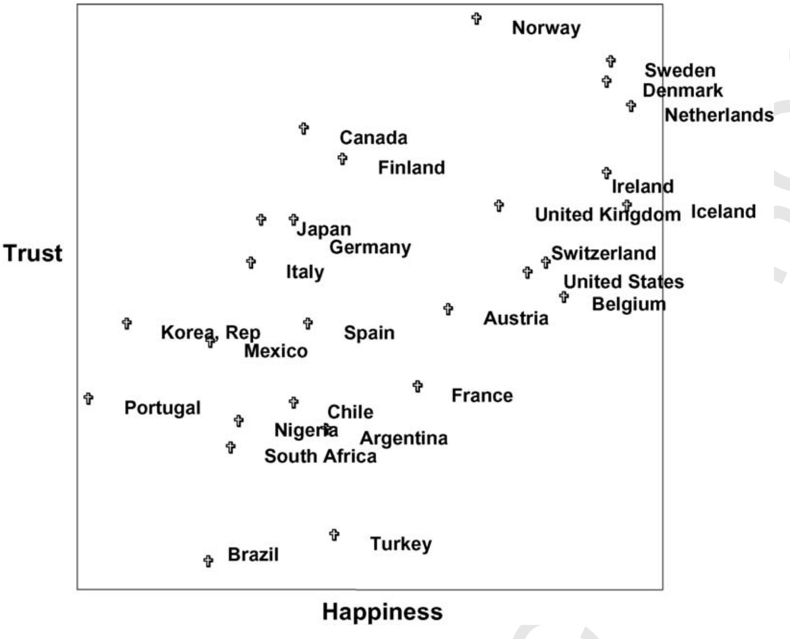

Fig. 5. Happiness and trust.

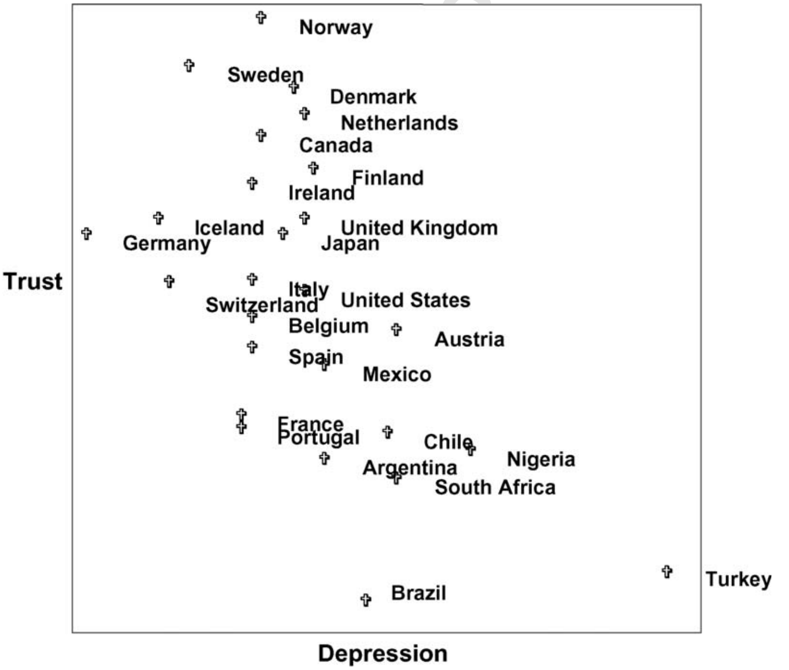

Fig. 6. Depression and trust.

to potentially raise trust levels, especially in developing countries. It also provides a development rationale for maintaining a clean environment and for the consumption of healthy foods.

Uncited references

Carter (2000), Evans (1997), Ferguson et al. (2000), Gazzaniga (2000), La Porta et al. (1999), Nemeroff (1998), United Nations (2001) and Zak (2005).

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Appendix A. Data sources and descriptive statistics

Data sources

Indicators, description and source
Social indicators:
Trust: percentage of respondents who answered yes to the question: "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?" *Source*: World Values Survey, 1995–1996.
Ownership: households in occupied housing units, % owner. *Source*: United Nations, Human Settlement Statistics Questionnaire 1999. http://www.unchs.org/habrdd/Statannex_A-4.pdf
Total breastfeeding: percent of breastfed infants. Exclusive breastfeeding rate (<4 months) + time complementary breastfeeding rate (6–9 months) + continued breastfeeding rate (12–15 months) + continued breastfeeding rate (20–23 months). *Source*: Breastfeeding indicators, UNICEF Global database.
Fertility rate: total births per woman. *Source*: World Development Indicators database, World Bank, 1990.
Female population: percentage of total population. *Source*: World Development Indicators database, World Bank, 1990.
Rural population: percentage of the total population. *Source*: World Development Indicators database, World Bank, 1990.
Sex frequency: respondents from the Global Sex Survey 2002 answering the question: "*How often do you have sex*". *Source*: Durex Global Survey. www.durex.com/scientific/studies/global/global3.html
Religion variables: International Social Survey Programme. *Source*: http://www.issp.org/
Telephone usage: mainlines per 1000 population. *Source*: World Bank: World Development Indicators
Eco-poor Indicators:
Distance from the equator: in degrees and minutes, of various major cities around the world.

Appendix A (*Continued*)

Source: http://geography.about.com/gi/dynamic/offsite.htm?once=true&site=http://www.bcca.org/misc/qib lih/latlong.html

Biodiversity: nationally protected area (% of land protected).
Source: The Little Green Data Book, 2001, World Bank Indicators

Water Pollution: emissions of organic water pollutants: (kgs per day per worker 1998) × 360
Emissions of organic water pollutants are measured in terms of biochemical oxygen demand (the amount of oxygen that bacteria in water will consume in breaking down waste).
Source: World Development Indicators, Table 3.6. World Bank

Density: population per square mile
Source: Population Reference Bureau, 1996, World Population Data, United Nations Population Division.

Air Pollution: three types: (Metric tonnes per capita)
Airp1: total suspended particulates refer to smoke, soot, dust, and liquid droplets from combustion.
Airp2: sulfur dioxide (SO_2) is an air pollutant produced when fossil fuels containing sulfur are burned.
Airp3: nitrogen dioxide (NO_2) is a poisonous, pungent gas formed when nitric oxide combines with hydrocarbons and sunlight.
Source: 1998 World Development Indicators, World Bank.

Per capita income: real income per capita in international prices, 1985.
Source: Summers and Heston, 1991.

Phytoestrogen Consumption: dietary intake of phytoestrogens (ug/day) × 360 based on the food frequency questionnaire in selected population.
Food types: (1) peas, dry; (2) beans, dry; (3) infant food; (4) rye: rye, flour rye, bran rye; (5) bovine meat: beef veal, beef boneless, beef dried salted and smoked, meat extracts, sausage beef, beef preparations, beef canned, meat homogenized, buffalo meat; (6) soybeans and products: soybeans, soya sauce, soya paste, soya curd; (7) spices: vanilla, cinnamon, nutmeg, anise, ginger, spices; (8) tea: tea, extract tea, mate.
Source: Food and Agriculture Organization of the United Nations.
http://apps.fao.org/page/form?collection=FS.CropsAndProducts&Domain=FS&servlet=1&language=EN&hostname=apps.fao.org&version=default

Institutional Indicators: International Country Risk Guide (ICRG)

Corruption in government: lower scores indicate ‘‘high government officials are likely to demand special payments’’ and ‘‘illegal payments are generally expected throughout lower levels or government’’ in the form of ‘‘bribes connected with import and export licenses, exchange controls, tax assessment, policy protection, or loans.’’ Scored 0–6.

Rule of law: This variable ‘‘reflects the degree to which the citizens of a country are willing to accept the established institutions to make and implement laws and adjudicate disputes.’’ Higher scores indicate ‘‘sound political institutions, a strong court system, and provisions for an orderly succession of power.’’ Lower scores indicate ‘‘ a tradition of depending on physical force or illegal means to settle claims.’’ Score 0–6.

Quality of bureaucracy: High scores indicate ‘‘autonomy from political pressure’’ and ‘‘strength and expertise to govern without drastic changes in policy or interruptions in government services’’, also ‘‘existence of an ‘‘establishment mechanism for recruiting and training’’. Scored 0–6.

Repudiation of contracts by the government: indicates the ‘‘risk of a modification in a contract taking form repudiation, postponement, or scaling down’’ due to ‘‘budget cutbacks, indigenization pressure, a change in government, or a change in government economic or social priorities.’’ Scored 0–10, with lower scores for higher risks.

Expropriation risk: assessment of the risk of ‘‘outright confiscation’’ or ‘‘forced nationalization.’’ Scored 0–10, with lower scores for higher risks.

Bureaucratic delays: Measures the ‘‘speed and efficiency of the civil service including processing customs clearances, foreign exchange remittances and similar applications.’’

Appendix A (*Continued*)

Contract enforcement: measures the ‘‘relative degree to which contractual agreements are honored.’’ Scored 0–4.

Nationalization risk: measures risk of ‘‘appropriation for no compensation’’ and ‘‘preferential treatment for nationals.’’ Scored 0–4, with higher scores for lower risks.

Infrastructure quality: assesses ‘‘facilities for ease of communication between headquarters and the operation, and within the country,’’ as well as quality of transportation. Scored 0–4, with higher scores for superior quality.

Ethnicity: Index of ethnolinguistic fractionalization, 1960. Measures the probability that two randomly selected people from a given country will not belong to the same ethnolinguistic group.
Sources: Business Environment Risk International (BERI), http://www.beri.com/brs.htm;
International Country Risk Guide, http://www.icrgonline.com; Sullivan, M. *Measuring Global Values*. Greenwood, 1991.

Happiness: Respondents answer the question: ‘‘How many days in the last week did you feel happy?’’.
Source: General Social Survey, 1996

Depression: Respondents answer the question: ‘‘How many days in the last week did you feel sad?
Source: General Social Survey, 1996

Descriptive statistics

	Mean	S.D.
Trust (■)	32.02	15.88
Income per capita (*)	7.96	4.87
Fertility (◘)	2.15	.92
Home ownership (□)	62.83	13.77
Density (▼)	381.16	478.03
Annual sex frequency (▶)	124.84	28.82
Breastfeeding (◀)	32.12	56.59
Distance from the equator (▲)	35.69	16.22
Telephone usage (■)	294.92	211.04
Air pollution (◆)	114.87	103.22
Water pollution (†)	367681.41	535831.27
Muslims (◇)	8.27	21.48
Catholics (◇)	42.70	36.98
Jews (◇)	1.64	8.81
Protestants (◇)	22.08	26.54
Buddhists (◇)	2.25	10.10
Hindus (◇)	2.58	13.02
Female population (○)	50.58	.73
Biodiversity (‡)	10.01	9.93
Share of rural population (●)	213.28	239.44
Happiness (♥)	3.12	.17
Depression (♥)	.20	.10
Corruption (♣)	4.09	1.31
Rule of Law (♣)	4.85	1.25
Bureaucracy (♣)	4.68	1.29
Ethnicity (♣)	4.90	1.10
Repudiation of contracts (♣)	9.20	1.02
Expropriation risk (♣)	9.75	.67
Bureaucracy delay (♣)	2.06	.56
Contract enforcement (♣)	2.58	.72
Nationalization risk (♣)	2.63	.56

Appendix A (*Continued*)

Infrastructure quality (♣)	2.47	.73
Secoisolariciresinol (♠)	34716.69	22438.85
Campesterol (♠)	2003.23	1109.44
Biochanin (♠)	42530.53	47790.49
Stigmasterol (♠)	2065.36	1305.60
Courmestrol (♠)	10963.15	18386.50
Genistein (♠)	148293.98	572098.72
Daidzein (♠)	91530.8	362430.82
Matairesinol (♠)	1103.69	1730.20
Myricetin (♠)	123171.46	102401.85
β-Sisterol (♠)	13591.18	6692.33
Boron (♠)	3940079.01	2831384.20
Quercetin (♠)	122188.01	178981.32
Kaempferol (♠)	73465.92	51866.26

(▯) Percentage of respondents who said they trusted most people. * Income real income per capita in 1985 international prices/1000. (❋) Total births per woman. (□) Percent of home owners in total population. (▼) Population per square mile. (▶) Frequency of sexual encounters per year. (◀) Percent of breastfed infants. (▲) Degrees and minutes. (■)Mainlines per 1000 population. (◆) Metric tonnes of CO_2, SO_2 and NO_2 per capita. (†) (kgs per day per worker 1998) × 360. (‡) Percent of land protected. (◇) Percent of total population. (○ and ●) Percentage of total population. (♥) Percent of population which feels happy/depressed. (♣) Scores between 0–6 or 0–10. See Appendix A. (♠) Dietary intake of phytoestrogens (ug/day) × 360 based on the food frequency questionnaire in selected population.

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