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Quantitative relations between corruption and economic factors

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Abstract. We report quantitative relations between corruption level and economic factors, such as country wealth and foreign investment per capita, which are characterized by a power law spanning multiple scales of wealth and investment per capita. These relations hold for diverse countries, and also remain stable over different time periods. We also observe a negative correlation between level of corruption and long-term economic growth. We find similar results for two independent indices of corruption, suggesting that the relation between corruption and wealth does not depend on the specific measure of corruption. The functional relations we report have implications when assessing the relative level of corruption for two countries with comparable wealth, and for quantifying the impact of corruption on economic growth and foreign investment.

PACS. 89.90.+n Other topics in areas of applied and interdisciplinary physics – 05.45.Tp Time series analysis – 05.40.Fb Random walks and Levy flights

1 Introduction

Corruption influences important aspects of social and economic life. The level of corruption in a given country is widely believed to be an important factor to consider when projecting economic growth, estimating the effectiveness of the government administration, making decisions for strategic investments, and forming international policies. The relation between corruption level and key parameters of economic performance is largely qualitative [1–8]. Corruption has become increasingly important with the globalization of the international economic and political relations between countries, which has led various governmental and non-governmental organizations to search for adequate measures to quantify levels of corruption [1,2,9–12].

Systematic studies of corruption have been hampered because of the complexity and secretive nature of corruption, making it difficult to quantify. There have been concerted efforts to introduce quantitative measures suitable for describing levels of corruption across diverse countries [13–15]. However, a specific functional dependence between quantitative measures of corruption and economic performance has not been established.

Previous studies have suggested a negative association between corruption level and country wealth [1–3]. There is active debate concerning the relation between corruption level and economic growth [16,17]. Some earlier studies suggest that corruption may help the most efficient firms bypass bureaucratic obstacles and rigid laws [4,5] leading to a positive effect on economic growth, while more recent works do not find a significant negative dependence between corruption and growth [1,2]. Further, studies of net flow of foreign investment report conflicting results. Some studies find no significant correlation between inward foreign investment and corruption level in host countries [6,7], while others indicate a negative association between corruption and foreign investments [2,8]. This debate reflects the inherent complexity of the problem as countries in the world vary dramatically in their social and economic development [18]. Thus, an open question remains whether there is a general functional relation between corruption level and key aspects of the economic performance of different countries.

We develop and test the hypothesis that there may be a power-law dependence between corruption level and economic performance which holds across diverse countries regardless of differences in specific country characteristics such as country wealth (defined in our paper as gross domestic product per capita) or foreign direct investment. Recent studies show that diverse social and economic systems exhibit scale invariant behavior — e.g.,

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size ranking and growth of firms, universities, urban centers, countries and even people's personal fortunes follow a power law over a broad range of scales [19–26]. Since countries in the world greatly differ in their wealth and foreign investments, we test the possibility that there may be an underlying organization, such that the cross-country relations between corruption level and country wealth, and corruption level and foreign investments exhibit a significant negative correlation characterized by scale-invariant properties over multiple scales, and thus they can be described by power laws. Specifically, we test if this scale-invariant behavior remains stable over different time periods, as well as its validity for different subgroups of countries. Finally, we demonstrate a strong correlation between corruption level and past long-term economic growth.

2 Data and methods

We analyze the Corruption Perceptions Index (CPI) [14,27] introduced by *Transparency International* [14], a global civil organization supported by a wide network of government agencies, developmental organizations, foundations, public institutions, the private sector, and individuals. The CPI is a composite index based on independent surveys of business people and on assessments of corruption in different countries provided by more than ten independent institutions around the world, including the *World Economic Forum*, *United Nations Economic Commission for Africa*, the *Economist Intelligence Unit*, the *International Institute for Management Development* [27]. The CPI spans 10-year period 1996–2005. The different surveys and assessments use diverse sampling frames and different methodologies. Some of the institutions consult a panel of experts to assess the level of corruption, while others, such as the *International Institute for Management Development* and the *Political and Economic Risk Consultancy*, turn to elite businessmen and businesswomen from different industries. Further, certain institutions gather information about the perceptions of corruption from *residents* with respect to the performance of their home countries, while other institutions survey the perceptions of *non-residents* in regard to foreign countries or specifically in regard to neighboring countries. All sources employ a homogeneous definition of corruption as the misuse of public power for private benefit, such as bribing public officials, kickbacks in public procurement, or embezzlement of public funds. Each of these sources also assesses the "extent" of corruption among public officials and politicians in different countries. Transparency International uses non-parametric statistics for standardizing the data and for determining the precision of the scores [27]. While there is a certain subjectivity in people's perceptions of corruption, the large number of independent surveys and assessments based on different methodologies averages out most of the bias. The CPI ranges from 0 (highly corrupt) to 10 (highly transparent).

We also analyze a different measure of corruption, the Control of Corruption Index (CCI) [9,15] provided by the *World Bank* [15]. The CCI ranges from –2.5 to 2.5, with positive numbers indicating low levels of corruption. As a measure of country wealth, we use the *gdp*, defined to be the annual nominal gross domestic product per capita in current prices in US dollars, provided by the *International Monetary Fund* (IMF) [28] over the 26-year period 1980–2005. As a measure of foreign direct investment we use annual data from the *Bureau of Economic Analysis* [29] of the United States (US) government, which represents the direct investment received by different countries from the US over the period 2000–2004. These data are appropriate for our study since (i) the US has been the dominant source of foreign investment in the past decades, and (ii) the 1977 Foreign Corrupt Practices Act (FCPA) [30] holds US companies legally liable for bribing foreign government officials, which makes the US a source country which penalizes its multinational companies for corruption practices [8].

3 Results and discussion

3.1 Relation between corruption level and country wealth

To test if there is a common functional dependence between corruption level and country wealth, we plot the CPI versus *gdp* for different countries (Figs. 1a–e). We find a positive correlation between CPI and country wealth, which can be well approximated by a power law

$$CPI \sim (gdp)^{\mu}, \tag{1}$$

where $\mu > 0$, indicating that richer countries are less corrupt. Most countries fall close to the power-law fitting line shown in Figure 1, consistent with specific functional relation between corruption and country wealth even for countries characterized by levels of wealth ranging over a factor of 10^3. This finding in equation (1) indicates that the relative corruption level between two countries should be considered not only in terms of *CPI* values but also in the context of country wealth. For example, two countries with a large difference in their *gdp* on average will not have the same level of corruption, as our results quantify the degree to which poorer countries with lower *gdp* have higher levels of corruption.

The quantitative relation between *CPI* and *gdp* for all countries in the world — represented by the power-law fitting curves in Figure 1 — indicates where is the "expected" level of corruption for a given level of wealth. A country above (or below) the fitting line is less (or more) corrupt than expected for its level of wealth. For example, comparing the relative corruption level of two countries with similar *gdp* such as Bulgaria and Romania, one can assess that Bulgaria is less corrupt than Romania (Fig. 3). Depending whether a specific country is above (e.g., Bulgaria) or below (e.g., Romania) the power-law fit, one can assess if this country is less (or more) corrupt relative to the average level of corruption corresponding to the wealth of this country.

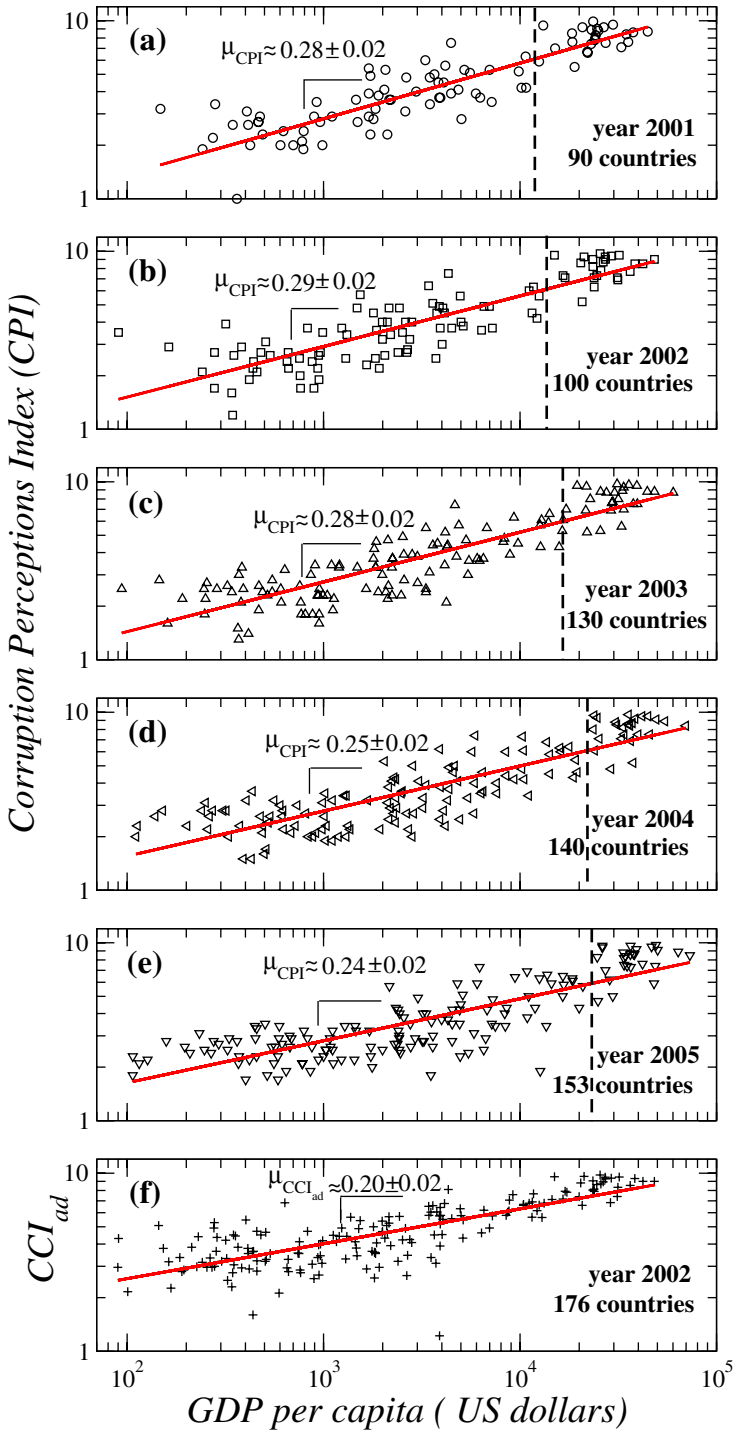

Fig. 1. Log-log plots of the corruption perceptions index (*CPI*) versus *GDP* per capita (*gdp*) indicating a power-law functional dependence. A low value of *CPI* corresponds to a high level of corruption [14]. Data on *gdp* are obtained as current prices in US dollars [28]. (a–e) The power-law functional dependence remains stable over different time periods, and is characterized by similar values of the exponent μ for different years and different number of countries. The power-law fit indicates the expected level of corruption for given country wealth. Note that, comparing two countries with a similar *gdp*, the country placed above the power-law fit is less corrupt than one would expect for its level of wealth, while the country below the power-law curve has a relatively higher level of corruption than one would expect for its wealth. (f) We obtain similar results for the *adjusted* control of corruption index CCI_{ad} [15], which is independent of *CPI*, indicating that the scale-invariant relation between corruption and wealth does not depend on the specific measure of corruption. Vertical dashed lines in the panels separate the top 30 wealthiest countries (see Figs. 5 and 6).

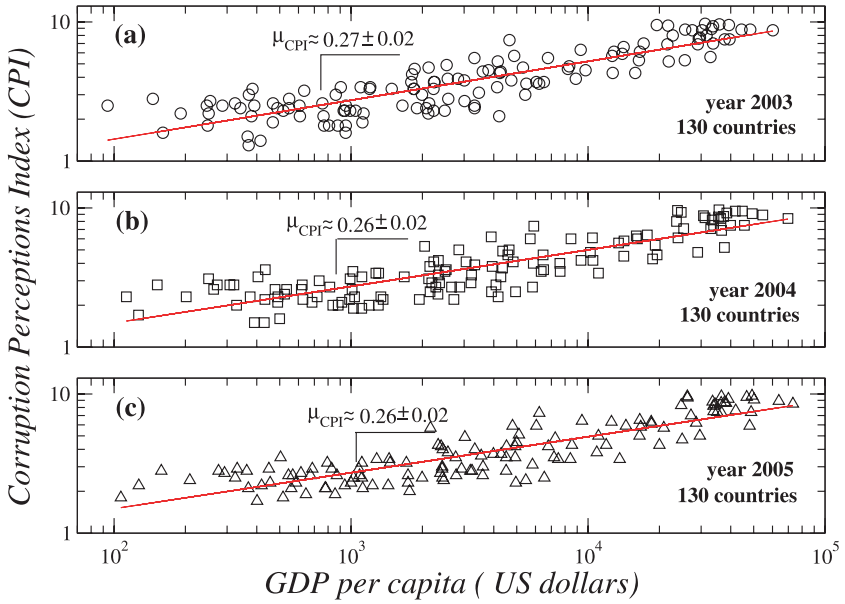

Fig. 2. Log-log plots of the corruption perceptions index (*CPI*) versus *GDP* per capita (*gdp*) for a subset of 130 countries over the period 2003–2005. The same set of countries is presented in each plot, indicating that the power-law exponent μ characterizing the relation between *CPI* and *gdp* remains relatively stable over the considered period. As rich countries have a relatively higher *gdp* growth rate compared to poor countries (see Fig. 9 below), and because *CPI* is defined in a bounded interval, we expect the value of the exponent μ to decrease slightly with time when considering time horizons larger than a decade.

Moreover, the quantitative dependence we find in equation (1) allows us to compare the relative levels of corruption between two countries which belong to two different wealth brackets. Specifically, two countries with a very different *gdp* should not be compared only by the value of their *CPI*, but also by their relative distances from the power-law fitting line which indicates the expected level of corruption. For example, Bulgaria and Slovenia differ significantly in their wealth (Slovenia has ≈5 times higher *gdp*), but both countries are at equal distances above the fitting line, indicating (i) that both countries are less corrupt than the corruption level expected for their corresponding wealth, and (ii) that the relative level of corruption of Slovenia within the group of countries falling in the same *gdp* bracket as Slovenia is similar to the relative corruption level of Bulgaria within the group of countries falling in the same *gdp* bracket as Bulgaria (Fig. 3).

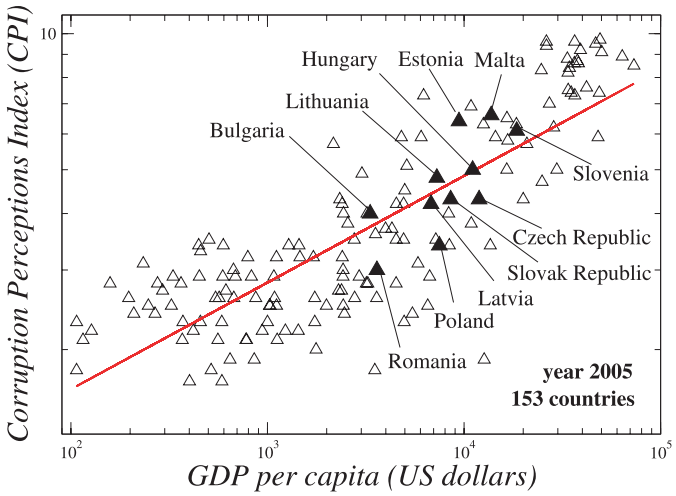

Fig. 3. Same as panel (e) in Figure 1 except we now identify by filled symbols the subset of the 153 countries, which are recently-accepted members of the European Union and candidates. Although this subset varies greatly in wealth and corruption level, data also follow a similar scale-invariant behavior.

To test how robust is the power-law dependence between corruption and country wealth, we analyze groups containing different numbers of countries for the period 2000–2005, and we find that equation (1) holds, with similar values of μ (Figs. 1a–e). Averaging the power-law exponent μ for different years and for different number of countries we find $\overline{\mu} \approx 0.27 \pm \Delta$, where $\Delta = 0.02$ is the standard deviation. For the *CPI* and *gdp* data we find an average correlation coefficient of 0.86. We also note that the inverse relation of *gdp* as a function of *CPI* is characterized by an exponent $\hat{\mu}$ which is not equal to $1/\mu$ as one might expect, since the correlation coefficient of the data fit is less than 1. Next, we analyze data comprising the same set of countries for different years (Fig. 2), and we find that the power-law dependence of equation (1) remains stable in time over periods shorter than a decade, with similar and slightly decreasing values for μ (Figs. 1 and 2). Similar results we obtain also for the period 1996–2000 (not shown in the figures as available data cover much smaller number of countries for that earlier period).

Given the facts that (i) the number of countries we analyze changes from 90 to 153, and (ii) that the time horizon of 5–6 years we consider could be sufficient for significant changes in both corruption level and wealth

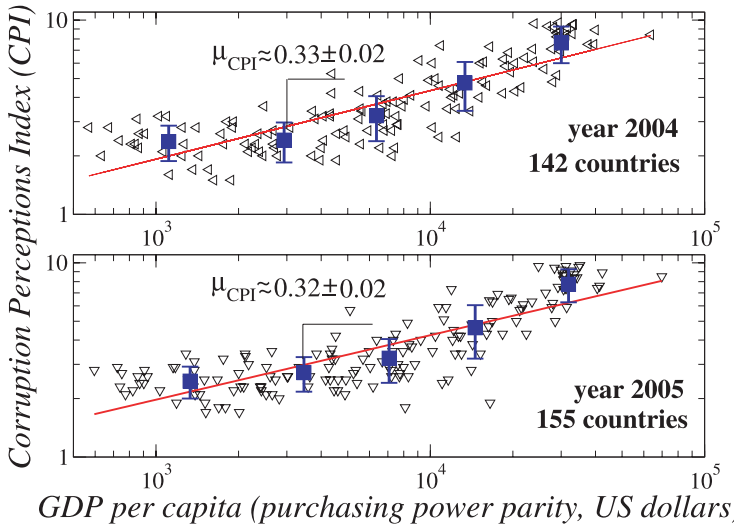

Fig. 4. Log-log plots of the corruption perceptions index (*CPI*) versus *GDP* per capita (*gdp*) for the same years as shown in panels (d) and (e) in Figure 1, indicating a power-law functional dependence similar to Figure 1. Data on *gdp* are obtained based on purchasing power parity in US dollars [28]. A low value of *CPI* corresponds to a high level of corruption [14]. The power-law relation between *CPI* and *gdp* remains stable also for constant prices across different years and different number of countries, and is characterized by a similar value of the exponent μ as for current prices. We note that the slightly higher value of μ_{CPI} observed here compared with Figures 1 and 2 is due to the slight reduction in the difference between wealthy and poor countries when *gdp* is measured based on purchasing power parity. The group average and standard deviation of the *CPI* for five subgroups of countries for both years are shown with filled squares. The power-law fit across all countries indicates the expected level of corruption for a given range of country wealth.

(e.g., the case of Eastern European countries), our finding of a power-law relationship in equation (1) is consistent with a universal dependence between *gdp* and *CPI* across diverse countries. We note that the power-law relation in equation (1) holds when *gdp* is calculated both as current prices in US dollars (Figs. 1 and 2), as well as the value based on purchasing power parity (Fig. 4). Further, equation (1) implies that lowering the corruption level of a country would lead to an increase in its *gdp* and vice versa — e.g., for a country with *gdp* $\approx$ \$4000 an increase in CPI of 0.25 units would lead to increase in the *gdp* of approximately \$700 (Figs. 1 and 2).

To confirm that our findings do not depend on the specific choice of the measure of corruption, we repeat our analysis for a different index, the CCI [9,15]. As the CCI is defined in the interval [–2.5, 2.5] we use a linear transformation to obtain the *adjusted* CCI, $CCI_{ad} \equiv 2\times(CCI+2.5)$, so that both CCI_{ad} and *CPI* are defined in the same interval from 0 to 10. We find that CCI_{ad} also exhibits a power-law behavior as a function of *gdp* with a similar value of the power-law exponent μ as obtained for *CPI* (Fig. 1f). Thus, the specific interval in which the corruption index is defined does not affect the nature of our findings. We note that there is no artificially imposed scale on the values of the *CPI* or CCI index for different countries. While the upper and lower bounds for the *CPI* or CCI index are indeed pre-determined, the intrinsic relative relation between the index values for different countries is inherent to the data. There is no logarithmic scale artificially imposed on the index values of each country (see details on the *CPI* and CCI methodology in [14,15,27]). The fact that we obtain practically identical results (power-law dependence with similar values of the exponent μ) for two independent indices *CPI* and CCI, which are provided by different institutions and are calculated using different methodologies, indicates that the quantitative relation of equation (1) is not an artifact of subjective evaluation of corruption. In summary, our empirical results indicate that the power-law relation between corruption and *gdp* across countries (i) does not depend on the specific subset of chosen countries (provided they span a broad range of *gdp*), (ii) does not depend on the specific measure of corruption (*CPI* and CCI), and (iii) does not change significantly over time horizons shorter than a decade.

3.2 Corruption level and country wealth rank curves

We next rank countries by their *gdp* and by their *CPI*. We find that *gdp* versus rank exhibits an exponential behavior for countries with rank larger than 30, and a pronounced crossover to a power-law behavior for the wealthiest 30 countries (Fig. 5). We further find that the shape of *gdp* versus rank curve remains unchanged for different years, and that increasing the number of countries we consider only extends the range of the exponential tail. Our findings for the shape of the *gdp* versus rank curve differ from earlier reports [31,32]. We find that the *CPI* versus rank curve exhibits a behavior similar to that of the *gdp* versus rank curve, with a crossover from a power law to an exponential tail for countries with rank larger than 30 (Fig. 5 and Fig. 6). The shape of the *CPI* versus rank curve also remains unchanged when we repeat the analysis for different years (Fig. 6). We find that the ranking of countries based on *gdp* practically matches the ranking based

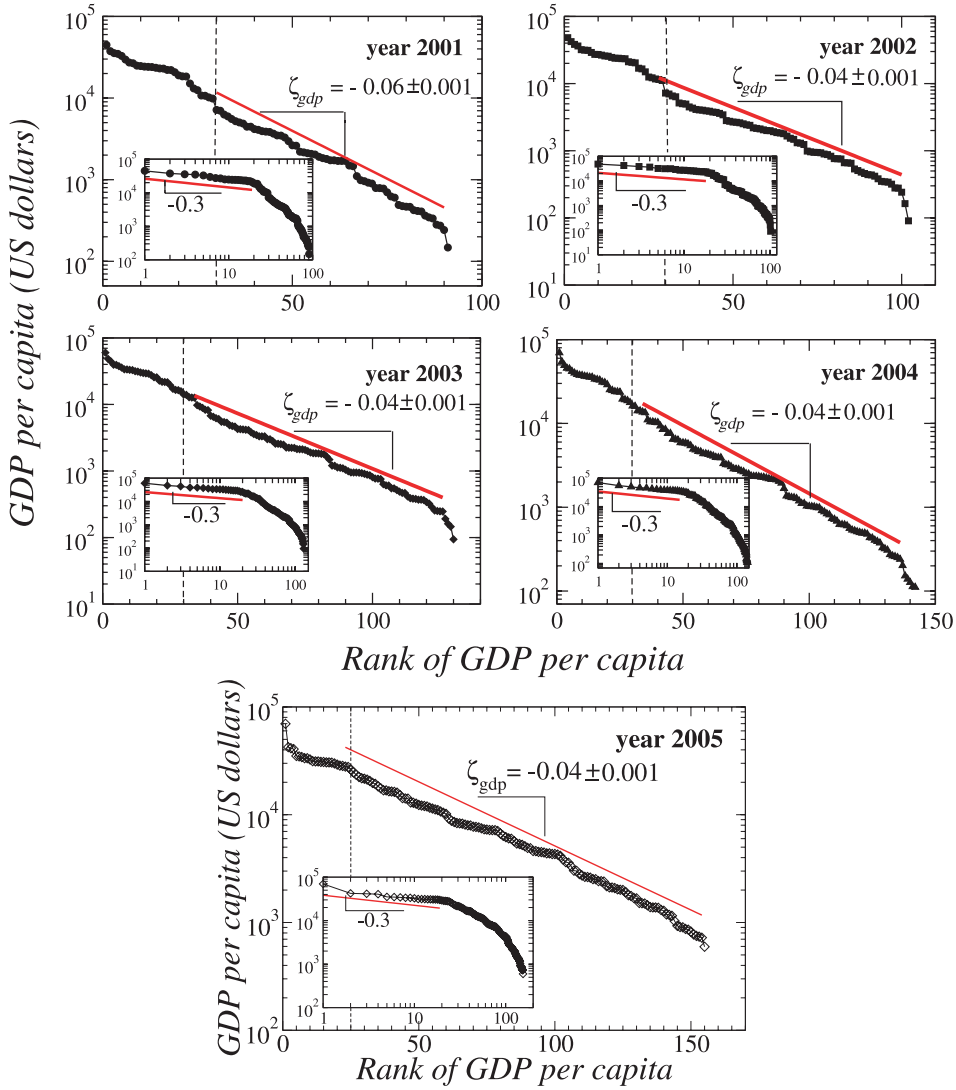

Fig. 5. Zipf plots ranking in decreasing order the *GDP* per capita (*gdp*) for the same groups of countries and for the same years as shown in Figure 1. Data on *GDP* per capita are obtained from the International Monetary Fund as current prices in US dollars [28]. Fitting lines indicate exponential behavior for the *GDP* per capita for countries below rank 30 (vertical dashed line, shown also in Figure 1), characterized by the exponential decay constant ζ_{gdp}. Log-log plots of the ranking curves (shown in the insets) indicate a crossover from an exponential to a power-law behaviour for the top 30 wealthiest countries. We note that the top 30 wealthiest countries cluster above the fitting curves in Figures 1, 2 and 4.

on the *CPI* index. This is evidence of a strong and positive correlation between the ranking of wealth and the ranking of corruption. Since the *gdp* rank is an unambiguous result of an *objective* quantitative measure, the evidence of a strong correlation of the *CPI* rank with the *gdp* rank we observe in Figures 5 and 6 indicates that the *CPI* values are *not subjective*, and that our finding of a power-law relation between *CPI* and *gdp* in Figures 1 and 2 is not an artifact of an arbitrary scale imposed on the *CPI* or on the CCI. Further, we compare the values of the decay parameters ζ_{CPI} and ζ_{gdp} characterizing the exponential behavior of the *CPI* and *gdp* rank curves,

$$CPI \sim \exp(\zeta_{CPI} \cdot R_{CPI}), \tag{2}$$

and

$$gdp \sim \exp(\zeta_{gdp} \cdot R_{gdp}), \tag{3}$$

where R_{CPI} and R_{gdp} is the rank order of *CPI* and *gdp* respectively.

We find that for each year the ratio ζ_{CPI}/ζ_{gdp} reproduces the value of the power-law exponent μ defined in equation (1) for the same year — an insightful result since it would hold only when R_{CPI} is similar to R_{gdp}. Indeed, only when $R_{CPI} \approx R_{gdp}$ we obtain from equation (2) and equation (3) the relation between $\log(CPI)$ and $\log(gdp)$,

$$log(CPI) \approx (\zeta_{CPI}/\zeta_{gdp}) \cdot log(gdp). \tag{4}$$

Combining equations (1) and (4), we see that

$$\mu = \zeta_{CPI}/\zeta_{gdp}. \tag{5}$$

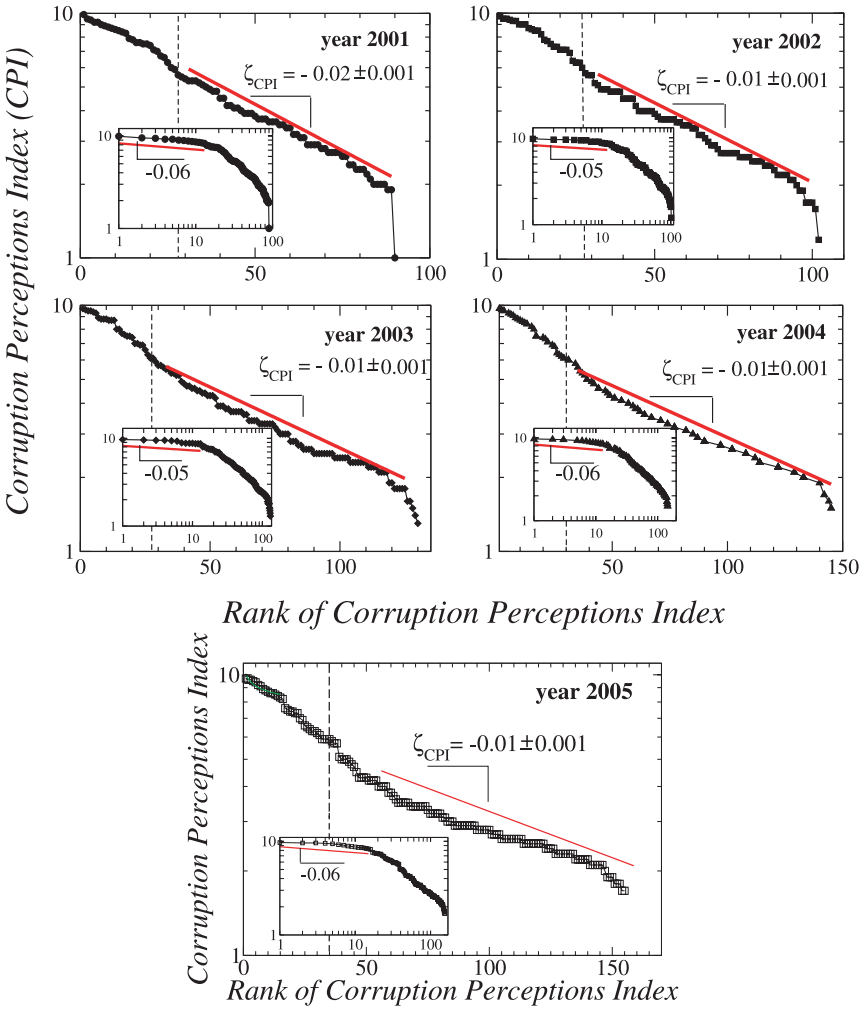

Fig. 6. Zipf plots ranking in decreasing order the *CPI* for the same groups of countries and for the same years as shown in Figures 1 and 5. Fitting lines indicate exponential behavior for the *CPI* for countries below rank 30 (vertical dashed line, shown also in Figs. 1 and 5), characterized by the exponential decay constant ζ_{CPI}. The ratio ζ_{CPI}/ζ_{gdp} consistently reproduces the value of the power-law exponent μ in Figures 1a–d for each corresponding year and each group of countries. This indicates that a necessary condition for the power-law relation between *CPI* and *GDP* per capita is that the *GDP* per capita rank order of countries is similar to the rank order based on CPI. Log-log plots of the ranking curves (shown in the insets) indicate a crossover from an exponential to a power-law behaviour for the top 30 least corrupt countries, similar to the crossover behaviour observed for *gdp* in Figure 5.

Thus, for each year the power-law dependence between *CPI* and *gdp* in equation (1) is directly related to the exponential relations of the *CPI* and *gdp* as a function of the rank shown in equation (2) and equation (3). We note that equation (5) does not hold for the top 30 wealthiest countries, for which there is an enhanced economic interaction in a globalization sense, perhaps leading to similarities in development patterns and to an overall decrease in the *gdp* growth difference between these countries [33,34].

3.3 Relation between corruption level and foreign direct investment

We next investigate how the corruption level relates to foreign direct investment. We consider the amount of inward investment received by different countries from the United States (US). Investments originating from the US are sensitive to corruption, since US legislation holds American investors in other countries liable for corruption practices [30]. We find a strong dependence of the amount of US direct investment in a given country on the corruption level in that country (Fig. 7). Specifically, we find that the functional dependence between US direct investment per capita, I, and the corruption level across countries exhibits scale-invariant behavior characterized by a power law ranging over at least a factor of 10^3 (Fig. 7)

$$CPI \sim I^{\lambda}. \tag{6}$$

We find that less corrupt countries have received more US investment per capita, and that equation (6) also holds for different years. In particular, we find that groups of countries from different continents, which differ both in *gdp* and in average *CPI*, are characterized by different values

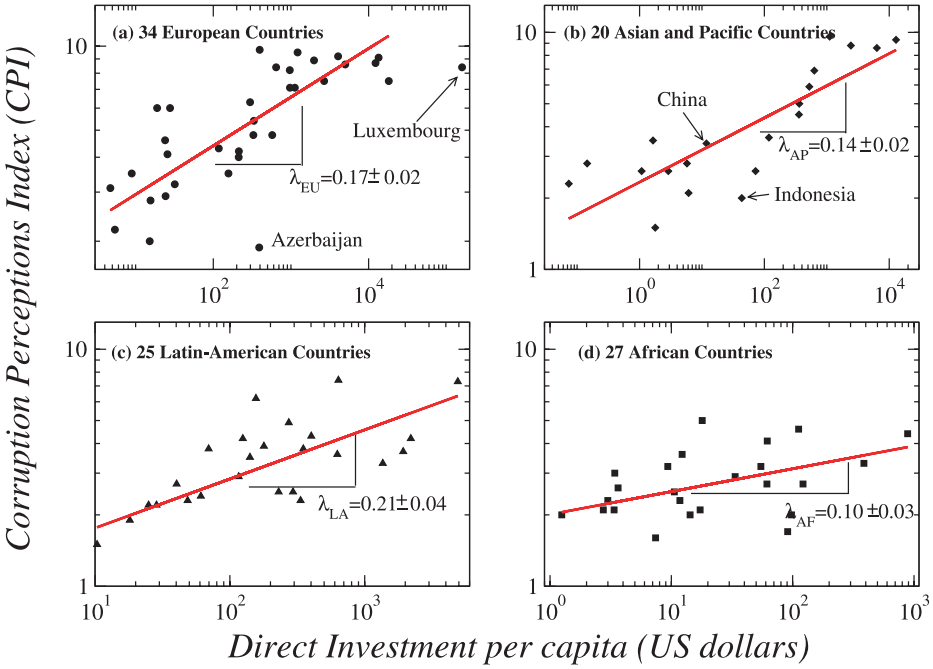

Fig. 7. Log-log plots of the *CPI* versus the amount of direct investment on a historical-cost basis from the United States received by different countries for the year 2004 [29]. We observe strong positive correlation between level of investment per capita and level of corruption — countries with high *CPI* receive also larger investment. Shown are (a) 34 European countries, (b) 20 Asian-Pacific countries, (c) 25 Latin-American countries and (d) 27 African countries. Note the striking difference between the typical values of direct investment per capita when comparing, say, European countries and African countries, with typical values of $CPI \approx 5$ and $CPI \approx 2.5$ respectively. The correlation coefficients of the fits in (a–d) are 0.74, 0.83, 0.69 and 0.37 respectively. Note that although China receives a huge net inflow of US investment each year, the per capita investment from the US is not very high, and is quite similar to the US per capita investment for countries with a *CPI* value similar to that of China.

of λ (Fig. 7). We obtain similar results when repeating our analysis for the CCI, suggesting that the power-law relation in equation (6) between corruption level and foreign direct investment per capita does not depend on the specific measure of corruption. We also note that the 1977 Foreign Corrupt Practices Act [30] only precludes American firms from entering corruption deals, but does not dictate in which country and how much money the American firms should invest. Therefore, the statistical regularities we find in Figure 7 cannot arise from legislatory measures against foreign corruption.

3.4 Relation between corruption level and growth rate

Finally, we investigate whether there is a relation between corruption level and long-term growth rate. Since the *CPI* reflects the quality of governing and administration in a given country, which traditionally requires considerable time to change, we hypothesize that there may be relation between the current corruption level of a country and its growth rate over a wide range of time horizons. To test this hypothesis we estimate the long-term growth rate for each country as the slope of the least square fit to the plot of $\log(gdp)$ versus year over the past several decades, where the *gdp* is taken as constant prices in national currency (Fig. 8). We divide all countries into four groups according to the World Bank classification based on *gdp* [35]. We find a strong positive dependence between country group average of *CPI* and the group average long-term growth

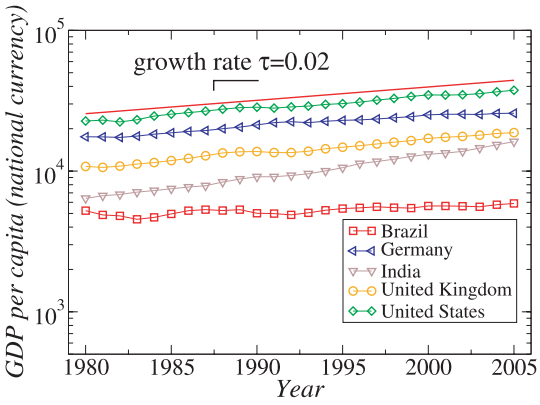

Fig. 8. Long-term growth rate of the *GDP* per capita (*gdp*) measured as constant prices in national currency [28] over the period 1980 to 2005. Separate curves represent countries of different wealth and corruption level from different continents. All countries exhibit exponential growth characterized by average long-term growth rate τ, estimated for each country as the slope of the least square fit to the plot of $\log(gdp)$ versus year over the period 1980 to 2005. The fitting line indicates the long-term growth rate τ of the United States over the period 1980 to 2005.

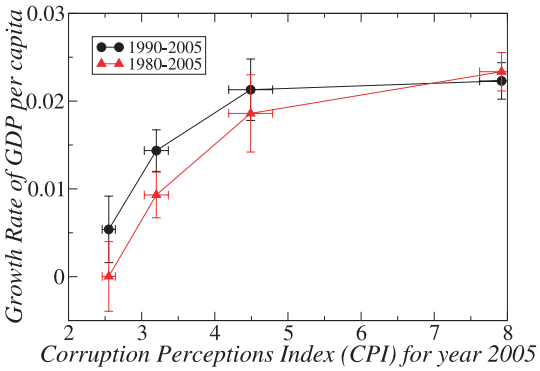

Fig. 9. Relation between the *CPI* for the year 2005 [14] and the long-term growth rate of *GDP* per capita (*gdp*) measured as constant prices in national currency [28]. Each curve represents 120 countries divided into 4 groups based on their level of wealth according to the World Bank's classification [35]. Excluded are countries with population less than two million and countries for which the *GDP* per capita records extend back fewer than 15 years starting from 2005. The long-term growth rate is estimated over the periods 1980–2005 and 1990–2005. Symbols represent the group average value of *CPI* and long-term growth rate of *GDP* per capita. The error bars represent the group standard error. The plot indicates that the corruption level of a country at present is strongly related to the past long-term growth rate of the *GDP* per capita. Countries which are presently more corrupt exhibit on average negligible or even negative growth rates. In contrast, less corrupt countries exhibit higher growth rates. This strong correlation between corruption level and growth rate of *GDP* per capita remains valid for a broad range of past time horizons.

rate, showing that less corrupt countries exhibit significant economic growth while more corrupt countries display insignificant growth rates (or even display negative growth rates) (Fig. 9). Repeating our analysis for different time horizons (1990–2005;1980–2005) we find similar relations between the *CPI* and the long-term growth, indicating a link between corruption and economic growth.

In summary, the functional relations we report here can have implications when determining the relative level of corruption between countries, and for quantifying the impact of corruption when planning foreign investments and economic growth. These quantitative relations may further facilitate current studies on spread of corruption across social networks [36], the emergence of endogenous transitions from one level of corruption to another through cascades of agent-based micro-level interactions [37,38], as well as when considering corruption in the context of certain cultural norms [39].

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