Corruption and innovation

Marcelo Veracierto

Introduction and summary

In this article, I illustrate how corruption can lower the rate of product innovation in an industry. This is important because, if many industries are subject to corrupt practices, the lower rate of innovation would result in a lower growth rate for the whole economy.[1] Actually, the view that corruption is closely related to economic development is widely held in practice: Poor African countries, such as Kenya and Zaire, are commonly believed to lose a considerable fraction of their gross domestic product (GDP) to corruption activities. Figure 1 illustrates the extent of this perception. It plots 2004 GDP per capita levels from the Penn World Table against the 2004 Corruption Perception Index constructed by Transparency International.[2] Since a Corruption Perception Index number close to zero indicates no corruption, figure 1 shows a clear negative relation between corruption and economic development.

While a negative correlation between corruption and GDP per capita levels is highly suggestive of an actual link, it is not conclusive evidence. It may be the case that corruption is closely related to other variables, such as political instability, the extent of violence, or the combativeness of unions, among other factors, and that these other variables are the ones generating poor economic development outcomes. In addition, GDP per capita levels may be affecting corruption levels and not the other way round. To complicate matters further, the negative correlation between corruption indexes and GDP per capita levels could be a mere artifact: It may well be the case that low GDP per capita levels are biasing the subjective perception of corruption reported by survey respondents. To disentangle the effects of corruption on economic development, further analysis is needed.

In this article, I provide theoretical grounds for pursuing such an analysis: In particular, I explore the strategic interactions between producers and corrupt officials. The basic corruption scenario considered involves three agents: an innovator, an incumbent producer, and a corrupt government official. The innovator wants to enter business by potentially paying a bribe; the incumbent producer wants to preclude the entry of the innovator by potentially paying a bribe; and the corrupt official decides on allowing the entry of the innovator based on the bribes received. Key elements of the game are that the government official can make successive take-it-or-leave-it bribe offers to the producers and that the central government can never verify the actual payment of a bribe (with some probability, the central government can detect that the entry permit was misallocated but cannot prove the actual amount of the bribe paid). Under these assumptions and within certain ranges, I show that the amount of bribes that the government official can collect can be very responsive to small changes in the probability of detection or in the penalties imposed. In fact, the bribe payments are shown to be a discontinuous function of those variables. Since the resources devoted to innovation are continuously and inversely related to the bribes that producers must pay, this means that the amount of resources devoted to innovation is a discontinuous function of the probability of detecting corruption and of the penalties imposed.

The rest of this article is organized as follows. In the next section, I discuss the related literature. Then, I describe the corruption game and characterize its solution. Next, I analyze the implications of the corruption game for innovation decisions. Finally, I draw some conclusions about my findings.

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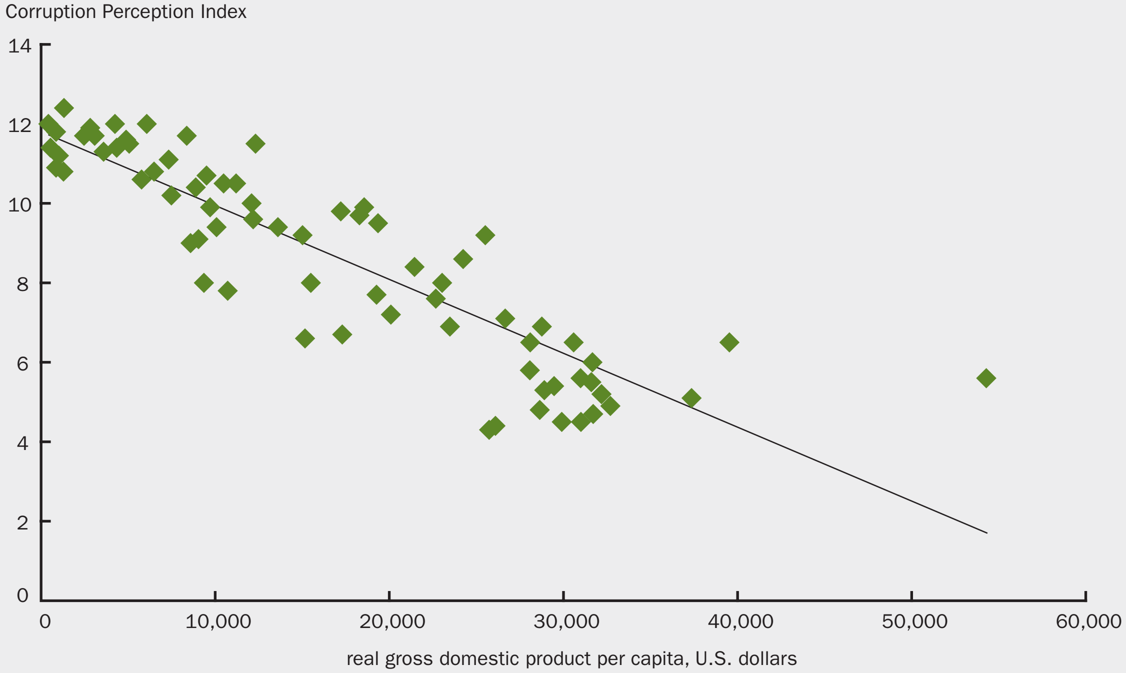
FIGURE 1

Corruption and real gross domestic product per capita



Notes: The Corruption Perception Index reported here is actually defined as 14 minus the Corruption Perception Index constructed by Transparency International. The transformation is made to associate low values for the index with low levels of corruption.
Sources: Author's calculations based on data from the University of Pennsylvania, Center for International Comparisons, Penn World Table; and Transparency International, Corruption Perception Index.

Related literature

Systematic empirical evidence about the relationship between corruption and economic development is hard to come by. A notable exception is the study by Mauro (1995). Using Business International Corporation's indexes on corruption, red tape, and efficiency of the judicial system over the period 1980–83 (now incorporated into the Economist Intelligence Unit), Mauro was able to estimate the direct effects of corruption on economic development. He found that corruption lowers investment, even controlling for other determinants of investment and endogeneity effects. The magnitude of the effect is quite significant. Mauro found that a one standard deviation improvement in the corruption index is associated with an increase in investment of 2.9 percent of GDP. This means, for example, that "if Bangladesh were to improve the integrity and efficiency of its bureaucracy to the level of that of Uruguay, its investment rate would rise by almost five percentage points, and its yearly GDP growth rate would rise by over half a percentage point" (Mauro, 1995, p. 705).

On the theoretical side, the literature has proceeded along two lines. One, following Becker and Stigler (1974), used a principal–agent approach. In particular, it focused on the incentives that the central government (the principal) can give a government official (the agent) to make him behave honestly. Another strand, following Shleifer and Vishny (1993), took the corrupt behavior of government officials as a given and analyzed the consequences that their behavior has on resource allocation. In this approach, corrupted officials are modeled as monopolistic suppliers of a government good (such as a passport, an import license, the right to use a road, etc.) that is supposed to be supplied at a prespecified price. The corrupt official overcharges the government good to maximize his total revenues.

More recently, Acemoglu and Verdier (2000) took a broader approach. They considered a static economy in which producers can choose to pay a cost in order to produce with a clean technology (otherwise, their production process pollutes the environment). The government wants to tax polluters and subsidize clean producers in order to reduce the associated negative externality. However, it must rely on officials to inspect the producers and determine their pollution status. The officials are assumed to be corrupt: Through bribes they are able to grab an exogenous share of the surplus, which is assumed to be equal to the sum of the tax and the subsidy that the official can potentially charge. As a consequence, the government faces an important trade-off between taxation and corruption: It wants to tax polluters, but in order to detect them it must rely on corrupted officials that consume resources. In this environment, Acemoglu and Verdier (2000) characterize the optimal amount of taxation/corruption.

While Acemoglu and Verdier (2000) were able to analyze the optimal taxation/corruption policy of the government, in order to do so they had to simplify the interaction between the government officials and the producers to a reduced form. My contribution to this literature is to spell out that interaction in an explicit game and analyze its implications in detail. Since Djankov et al. (2002) report that there are large differences across countries in the regulation of entry and that this type of regulation is associated with sharply higher levels of corruption, I formulate the corruption game in the context of entry decisions to an industry.[3]

The corruption game

The corruption game is as follows. Consider the case of a product line that is supplied by a single producer—the incumbent. The value of supplying the product line is given by V. In addition, there is a potential producer that has just created a new product generation—the innovator. If the innovator is allowed to supply the new product, the incumbent will be driven out of the market. As a consequence, the innovator would obtain the value V and the incumbent would lose it. Entry is regulated: The innovator must receive permission from the government to enter business. The reason for the regulation is that the innovator may produce with a technology that pollutes the environment. The government is willing to grant the entry permit to the innovator only if the new production technology is clean. However, the government must send a government official to determine whether the new technology pollutes or not. Once the government official inspects the new technology, its pollution status becomes fully known to him. After the official learns the pollution status of the new technology, he must report it to the central government. If the official reports that the new technology pollutes the environment, the innovator is precluded from producing but faces no additional penalties.[4]

The government official is corrupt. He has the ability of misrepresenting to the government the true pollution status of the new technology. This allows him to try to extract a bribe, either from the incumbent or the innovator, in determining which report to make to the central government. For simplicity, I assume that the pollution status of the new technology is fully known to both the innovator and the incumbent. This means that once the government official inspects the new technology, its pollution status becomes common knowledge to the three parties—the incumbent, the innovator, and the official.

The government never observes the actual bribe payment received by the official. However, once the official makes his report, with probability φ the government independently learns about the true pollution status of the new technology. If the official is found to have granted an entry permit to a polluter, there are penalties involved. In particular, the official is fined pV, while the innovator is fined mV. If the official is found to have rejected an entry permit to a clean innovator, there are also penalties involved: The official is fined pV, and the incumbent is fined mV.

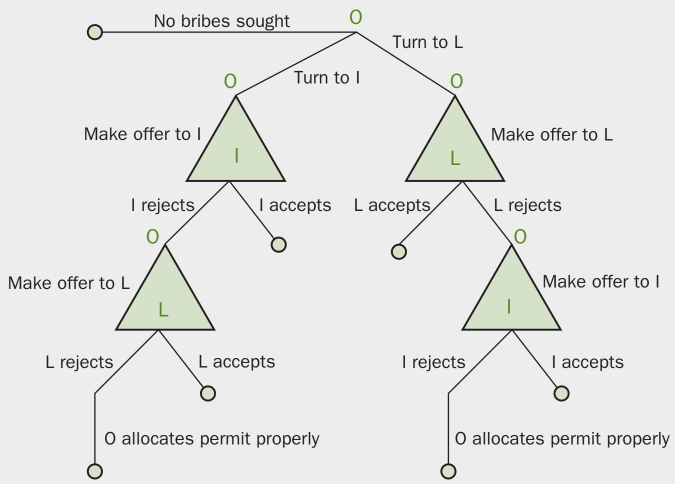
The official is assumed to be able to make take-it-or-leave-it offers. The key decision for the official is whether to request a bribe and from whom. In what follows, we will see that the best strategy for the official is to turn to the producer with the largest joint surplus and make him a take-it-or-leave-it offer. However, for the producer with the largest joint surplus to accept this bribe proposal, it must be credible that the producer with the second largest joint surplus would be willing to accept a bribe proposal if offered one. This will require the second largest joint surplus to be positive.

In principle, two possible scenarios must be considered: the scenario in which the innovator does not pollute the environment and the scenario in which the innovator does pollute the environment. However, the two scenarios are completely symmetrical. In each scenario there is a “legal” producer and an “illegal” producer. In the case that the innovator pollutes, the legal producer is the incumbent; in the case that the innovator does not pollute, the legal producer is the innovator. Moreover, the payoffs to each player in the corruption game only depend on whether the bribes are being extracted from the legal producer or the illegal producer (that is, the payoffs are independent of the actual identity of the producers). Given this symmetry, in what follows I consider a single corruption game that differentiates producers only according to their legal status, with the understanding that the identities of the legal and illegal producers are determined by the actual scenario taking place.

Figure 2 describes the sequence of moves for the corruption game. In the first stage, the government

FIGURE 2

Sequence of moves for corruption game



Notes: I refers to illegal producer; L to legal producer; and O to government official. See the text for further details.

official must decide between three alternatives: 1) not to seek bribes, 2) to initially seek a bribe from the illegal producer *I*, and 3) to initially seek a bribe from the legal producer *L*. In the case that the official seeks a bribe, he must decide how much to demand from the producer he initially turns to (the continuum of values for the bribe are represented as the base of the triangles in figure 2). If the bribe request is accepted, the game ends. Otherwise, the official turns to the second producer and decides how much to demand from him. The game ends after this point. If this bribe request is rejected, the official assigns the production permit to the legal producer, since he has nothing to gain otherwise. In what follows, I analyze the way that the corruption game is played.

First, observe that the government official always has a larger joint surplus to share with the legal producer than with the illegal producer. The reason is that the value of being the product leader is the same for both types of producers, but there are penalties involved if a deal with the illegal producer is subsequently detected. In addition, the value of not being the product leader is the same for both types of producers (in particular, it is equal to zero). This means that the government official will always want to extract bribes from the legal producer. However, for the legal producer to be willing to pay such a bribe, it should be credible that the government official would want to reach a deal with the illegal producer in a second round of negotiation. If this is not the case, the legal producer will reject any bribe request, since he knows that the government official will subsequently take the legal course of action.

Observe that the payoff to the illegal producer of reaching a deal with the government official is:

$$P_I = V - B_I - \varphi\,[V + mV],$$

where B_I are the bribes paid. This payoff is equal to the value of being the product leader net of the bribe payment minus the losses if the deal is detected, an event that happens with probability φ. Since the payoff to the illegal producer of rejecting the bribe is zero, the largest bribe that the government official would be able to extract from the illegal producer in a take-it-or-leave-it offer is given by:[5]

$$1)\qquad B_I = (1-\varphi)V - \varphi mV.$$

The payoff to the government official in this case is

$$P_O = B_I - \varphi pV = (1-\varphi)V - \varphi mV - \varphi pV.$$

That is, it is the maximum bribe that the government official could extract from the illegal producer minus the penalty pV times the probability φ of being caught by the central government.

The condition that this payoff P_O is positive reduces to

$$2)\qquad \frac{1-\varphi}{\varphi} > m + p.$$

If this condition is not satisfied, it would be in the best interest of the government official not to seek a bribe from the illegal producer. Hence, the legal producer would reject any take-it-or-leave-it offer made by the official and the legal course of action would be taken. If the condition in equation 2 is satisfied, the government official would be able to extract bribes from the legal producer, since it becomes fully credible that he would subsequently want to reach a deal with the illegal producer.

Observe that the payoff to the legal producer of reaching a deal with the government official is:

$$P_L = V - B_L.$$

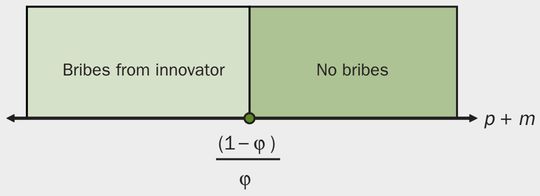
That is, it is equal to the value of being the product leader net of the bribes paid. This payoff is nonrandom because if the central government independently learned about the pollution status of the innovator, it would conclude that the entry permit was correctly allocated (recall that the central government can never prove that a bribe payment took place). Also, the payoff to the legal producer of rejecting a bribe offer from the government official is φV, since with probability φ the illegal action will be detected by the central government and the legal producer will become the product leader. Hence, the largest bribe that the government official will be able to extract from the legal producer is:[6]

$$3) \quad B_L = (1 - \varphi)V.$$

To summarize, the equilibrium of the corruption game is as follows. If the condition in equation 2 is violated, no bribes are paid. If the condition in equation 2 is satisfied, the government official extracts from the legal producer the bribes given by equation 3. In both cases, the official takes the legal course of action. Figure 3 provides an illustration of the equilibrium outcome.

FIGURE 3

Equilibrium outcomes in parameter space



Note: See the text for further details.

Innovation decisions

In this section, I describe in detail the industry in which the incumbent and innovator of the previous section operate. The purpose is to determine how corruption affects the industry's innovation rate.

The industry produces a product that comes in many possible qualities. At each point in time, there is a frontier version that dominates all previous ones. A single producer has the patent to this version. He drives all other producers out of the market and enjoys a profit flow equal to Π. However, he loses his leading position whenever an innovator enters business with a quality improvement. In this case, the incumbent is driven out of the market, and the innovator becomes the new industry leader, which provides him the profit flow Π.

Product innovations take place at an endogenously determined rate η. At every point in time there are a large number of potential producers (innovators) that invest in research and development (R&D) in order to create a new product generation. They all face a same cost function $r(\eta)$, which describes the costs of generating an arrival rate equal to η.[7] If an innovator succeeds in creating the new product generation, he can apply for an entry permit. If the entry permit is awarded, the innovator becomes the new industry leader. However, entry is regulated as in the previous section. In particular, a government official is sent to inspect the pollution status of the new technology. As a result, the official, the incumbent producer, and the innovator end up playing the corruption game described before. The probability that an entry application is inspected by a government official is equal to γ, while the probability that an innovation pollutes is equal to ξ.

The optimization problem of an innovator is then the following:

$$4) \quad \max \{\eta\, [\xi N_P + (1 - \xi)\, N_C\,] - r\,(\eta)\},$$

where N_P is the value of being an innovator that pollutes and N_C is the value of being an innovator that produces with a clean technology. That is, the innovator chooses the arrival rate η to maximize the expected value net of R&D costs. The optimal innovation rate η is characterized by the following condition:

$$5) \quad r'\,(\eta) = \xi N_P + (1 - \xi)\, N_C\,.$$

That is, the innovator equates marginal revenue to marginal cost. In what follows, I sketch the main properties of the optimal R&D investment decisions both from an individual point of view and at the industry level. The appendix provides a more detailed analysis.

To start with, observe that the marginal cost function r' is strictly increasing. Thus, given fixed values for N_P and N_C, there is a unique value of η that satisfies equation 5. While an individual innovator takes the values of N_P and N_C as given (since he is competitive), these values actually depend on the industry-wide innovation rate η^*. Moreover, they are strictly decreasing in the industry-wide innovation rate η^*. The reason is that given all other parameter values, an increase in η^* decreases the expected length of time over which a producer can retain the leadership of a product line (that is, it increases the rate at which future innovators will drive him out of the market). Thus, the expected value

$$\bar{N} = \xi N_P + (1-\xi) N_C$$

in the right-hand side of equation 5 is strictly decreasing in η^*. At equilibrium, the industry-wide innovation rate η^* that innovators take as given (and that determines the expected value $\bar{N}$) must be identical to the one they choose from their individual perspective. That is, at equilibrium we must have that the innovation rate satisfies:

$$6) \quad r'(\eta^*) = \bar{N}(\eta^*).$$

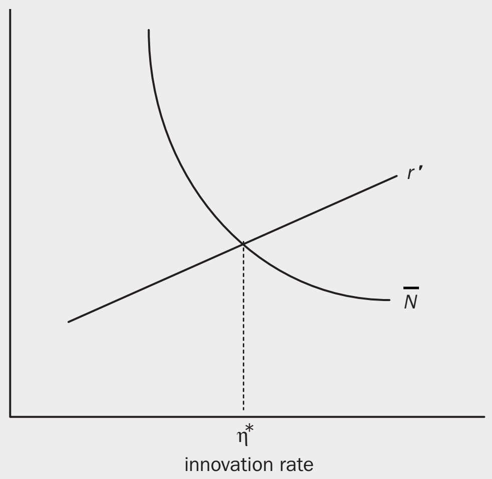
Since the left-hand side of equation 6 is strictly increasing in η^* and the right-hand side of equation 6 is strictly decreasing in η^*, there is a unique value of η^* that satisfies this equation. That is, there is a unique industry equilibrium. Figure 4 illustrates this equilibrium.

We are interested in how the equilibrium innovation rate η^* is affected by changes in different parameter values. While the appendix provides a formal analysis, the results are quite intuitive. We saw in the previous section that the penalties to the government official and illegal producer (p and m, respectively) affect whether bribes are paid or not but do not affect the magnitude of the bribes. In particular, if the condition in equation 2 is satisfied, bribes are paid. However, p and m do not enter equation 3, which describes the equilibrium bribes B_L that the government officials are able to extract from the legal producers. This means that as long as $p + m > (1 - \varphi)/\varphi$, the expected value $\bar{N}$ is independent of those penalties; but as soon as $p + m$ becomes equal to $(1 - \varphi)/\varphi$, the expected value $\bar{N}$ plummets because now producers become subject to bribes. Further, decreases in $p + m$ have no additional effects in $\bar{N}$. The implications for the equilibrium innovation rate are shown in figure 5. The curve $\bar{N}_1$ describes the expected value of innovating in the case in which there are no bribes (that is, when $p + m > (1- \varphi)/\varphi$), while the curve $\bar{N}_2$ describes the expected value of innovation when producers pay bribes (that is, when $p + m < (1 - \varphi)/\varphi$). Since $\bar{N}_2$ is lower than $\bar{N}_1$ for every value of η, it follows that the equilibrium innovation rate with bribes η_2^* must be lower than the equilibrium innovation rate when there are no bribes η_1^*. This leads to my main result: The effects of penalties to corruption on equilibrium innovation rates are highly nonlinear. In particular, small changes in penalties $p + m$ around the critical value $(1 - \varphi)/\varphi$ can lead to large changes in innovation rates, while changes in penalties far from that critical value have no effects. The discontinuous dependence of the equilibrium innovation rate η^* on the total penalties $p + m$ is depicted in figure 6.

The effects on the equilibrium innovation rate of changes in the probability of detecting corruption φ and in the fraction of entry applications that get inspected γ are more complex, since they not only determine whether bribes are paid, but also affect the position of

FIGURE 4

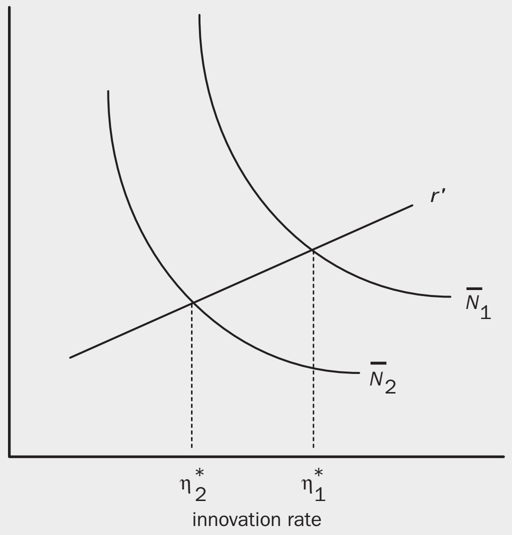
Industry equilibrium



Note: See the text for further details.

FIGURE 5

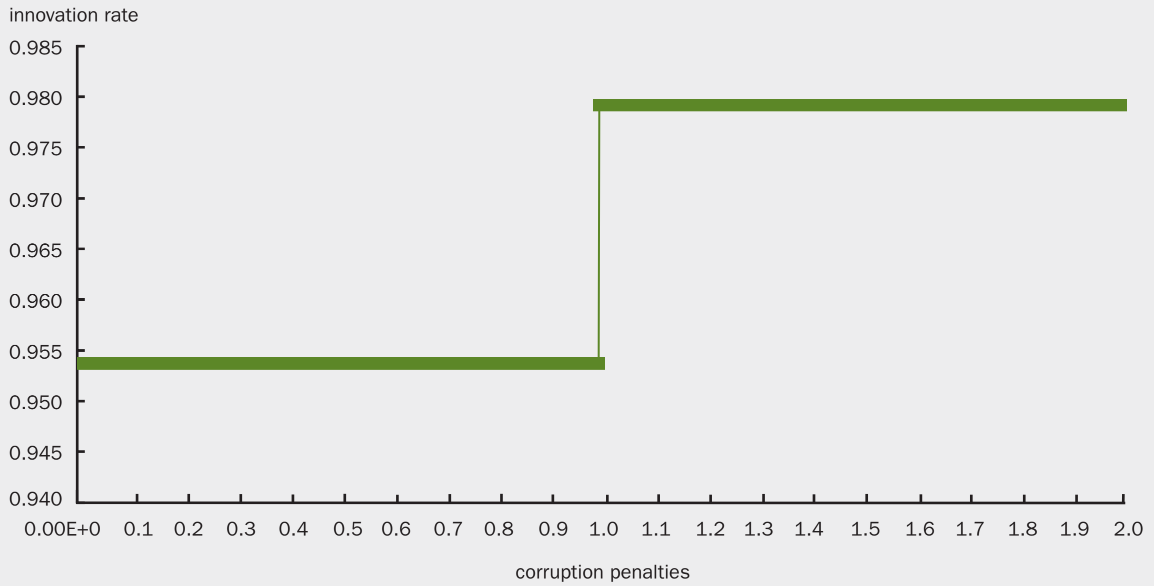
Innovation rates with (η_2^*) and without (η_1^*) bribes



Note: See the text for further details.

FIGURE 6

Innovation rate (η^*) vs. corruption penalties ($p + m$)



the curves $\bar{N}_1$ and $\bar{N}_2$ in figure 5. A numerical analysis of these effects is provided in the appendix.

Conclusion

I have illustrated how the rate of product innovation can be affected by changes in parameter values determining the amount of corruption in an industry. An interesting result of the analysis is that, under certain parameter ranges, small increases in the penalties to corruption or the effectiveness of detection can result in large increases in the amount of product innovation.

While I have not explicitly analyzed the effects of innovation on economic development, it is safe to speculate what those effects would be. To be specific, consider Grossman and Helpman's (1991) endogenous growth model. In that model, there is a continuum of product lines, each characterized by quality ladders of fixed increments. In each product line, there is always a leader producer that supplies the frontier quality and drives all previous producers out of the market. However, the arrival rate of innovators is optimally determined in an R&D sector. Successful innovators drive the incumbent leaders out of the market and become the new product leaders. Thus, each product line has a similar structure as the industry considered in this article. Introducing a corruption game in each product line would thus deliver similar results. Since in Grossman and Helpman (1991) the growth rate of the economy is determined by the endogenous innovation rate, the effects of corruption found here would translate into growth effects. In particular, small increases in the penalties to corruption or the effectiveness of detection can lead to jumps in the growth rate of the economy. Thus, corruption has the potential of grouping countries into two distinct development groups: fast- and slow-growing countries.

NOTES

[1]While I do not explicitly analyze the links between corruption, innovation, and economic growth, I sketch them in some detail in the conclusion.

[2]The Penn World Table—maintained by the Center for International Comparisons at the University of Pennsylvania—provides purchasing power parity and national income accounts converted to international prices for 188 countries for some or all of the years 1950–2004. For further details, please see http://pwt.econ.upenn.edu/. Transparency International is a global organization promoting anticorruption policies. Its Corruption Perception Index ranks countries by the perceived levels of corruption (frequency and/or size of bribes) in the public and political sectors, as determined by expert assessment and business opinion surveys. The Corruption Perception Index can be downloaded from www.transparency.org.

[3]For example, Djankov et al. (2002) report that to meet government requirements for starting a business in 1999, an entrepreneur in Italy needed to follow 16 different procedures, pay US$3,946 in fees, and wait at least 62 business days to acquire the necessary permits. In contrast, an entrepreneur in Canada only needed to follow two procedures, pay US$280, and wait for two days. An extended account of how entry regulation leads to corruption and bureaucratic delays is provided by De Soto (1989). However, he focuses on the Peruvian economy.

[4]Introducing a fine to polluters would significantly complicate the analysis of the corruption game without additional insights.

[5]This bribe request makes the illegal producer indifferent between accepting and rejecting it.

[6]This bribe request makes the legal producer indifferent between accepting and rejecting it.

[7]This cost function is assumed to be increasing, differentiable, and strictly convex. Moreover, $r'(0) = 0$ and $r'(\infty) = \infty$.

APPENDIX: RESEARCH AND DEVELOPMENT DECISIONS AND INDUSTRY EQUILIBRIUM

Given the solution to the corruption game characterized in the main text, we can proceed to write expressions for N_P and N_C. The expected value of an innovator that does not pollute N_C is given by:

$$N_C = \begin{cases} V \text{ if } p+m > \dfrac{(1+\varphi)}{\varphi} \\ (1-\gamma)V + \gamma\varphi V, \text{ otherwise} \end{cases}.$$

Observe that when $p+m > \frac{(1+\varphi)}{\varphi}$, there are no bribes paid in the corruption game. Hence, the clean innovator obtains the value V of becoming a leader with certainty. When $p+m < \frac{(1+\varphi)}{\varphi}$, bribes are paid whenever the innovator gets inspected. As a consequence, the innovator gets the full value V only if he is not inspected, an event that happens with probability $(1-\gamma)$. With probability γ, the (clean) innovator is inspected and obtains a value (net of bribes) of φV.

The expected value of an innovator that pollutes N_P is given by:

$$N_P = (1-\gamma)\, V.$$

The innovator that pollutes obtains the full value of becoming the leader V only if he is not inspected, which happens with probability $(1-\gamma)$. With probability γ, the innovator that pollutes is inspected and is precluded from producing (recall that for every parameter specification the government official always takes the legal course of action).

The value of being the industry leader V is given as follows:

$$iV = \begin{cases} \Pi - \eta V + \eta\xi\gamma V \text{ if } \dfrac{(1-\varphi)}{\varphi} < p+m \\ \Pi - \eta V + \eta\xi\gamma\varphi V, \text{ otherwise} \end{cases},$$

where i is the instantaneous interest rate. The flow value of being the leader iV is given by Π, but with arrival rate η, a new innovator enters the market, in which case the profit flow Π is permanently lost. However, there are exceptions to this loss. When $\frac{(1-\varphi)}{\varphi} < p+m$, the loss is avoided when the new arrival pollutes and is inspected by a government official, an event that happens with probability $\xi\gamma$ (in this case there are no bribes imposed and the entry permit is rejected). Also, when $p+m < \frac{(1-\varphi)}{\varphi}$, the loss is partly avoided when the new arrival pollutes and is inspected by a government official (again, an event that happens with probability $\xi\gamma$). However, in this case, the leader is only able to retain a fraction φ of the value of being the leader V.

We are now ready to write the expected value of creating a new product generation in equation 4 (p. 33):

$$\bar{N} = \xi N_P + (1-\xi) N_C.$$

This expected value depends on parameter values, since the outcome of the corruption game varies depending on them. As a consequence, I will index the expected value $\bar{N}_j$ according to the parameter region j.

Parameter region $1 (j = 1): \frac{(1-\varphi)}{\varphi} < p + m,$

A1) $\bar{N}_1(\eta) = \{\xi(1-\gamma)+(1-\xi)\}\frac{\Pi}{i+\eta-\eta\xi\gamma}.$

Parameter region $2 (j = 2): p + m < \frac{(1-\varphi)}{\varphi},$

A2) $\bar{N}_2(\eta) = \{\xi(1-\gamma)+(1-\xi)[(1-\gamma)+\gamma\varphi]\}$
$\frac{\Pi}{i+\eta-\eta\xi\gamma\varphi}.$

Observe that, in each parameter region j, the expected value $\bar{N}_j(\eta)$ depends on the industry's arrival rate η, which is an endogenous variable of the model. In particular, the expected values $\bar{N}_j(\eta)$ depend negatively on η. Also, it is straightforward to verify that for every possible value of the arrival rate η, that

A3) $\bar{N}_2(\eta) < \bar{N}_1(\eta).$

Observe that, since r is a convex function, r' is increasing in η. This, together with the previously mentioned properties for the expected values $\bar{N}_j(\eta)$, allows us to establish that in each parameter region j there is a unique equilibrium arrival rate η_j^* satisfying that

$$r'(\eta_j^*) = \bar{N}_j(\eta_j^*),$$

and that these arrival rates are ordered across parameter regions as follows:

A4) $\eta_2^* < \eta_1^*.$

As mentioned in the main text, this inequality leads to the main result of the article. Fixing all other parameter values, lower penalties on corruption $p + m$ lead to lower rates of innovation. However, the relation is highly nonlinear. Reductions in $p + m$ have no effects on rates of innovation as long as they leave the model within the same parameter region. But once the edge of a parameter region is approached, small reductions in $p + m$ have large effects as the equilibrium innovation rate η^* jumps from one region to the next.

The effects of the probability of detection φ and the fraction of entry applications that get inspected γ are more complex because they affect not only the length of the parameter regions but also the position of the expected values $\bar{N}_1$ and $\bar{N}_2$ in figure 5 (p. 34). To ease the presentation of these effects, in what follows I complement the analysis with a numerical example. It is important to point out that the example has no empirical content, since parameter values are not chosen to reproduce observations; it serves illustration

FIGURE A1

Innovation rate (η^*) vs. probability of detecting corruption (φ)

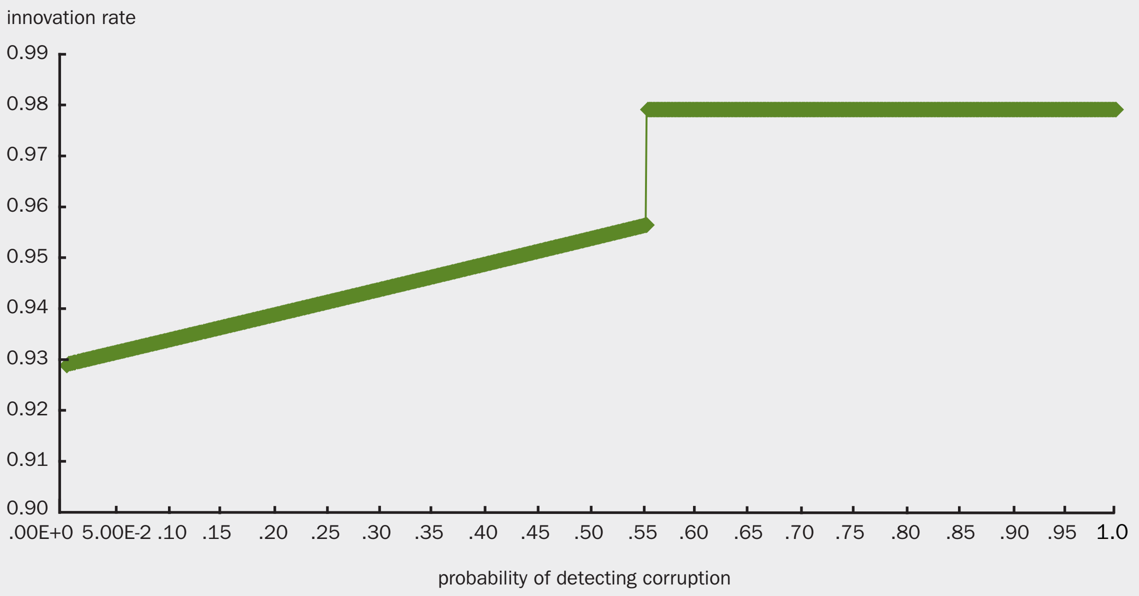
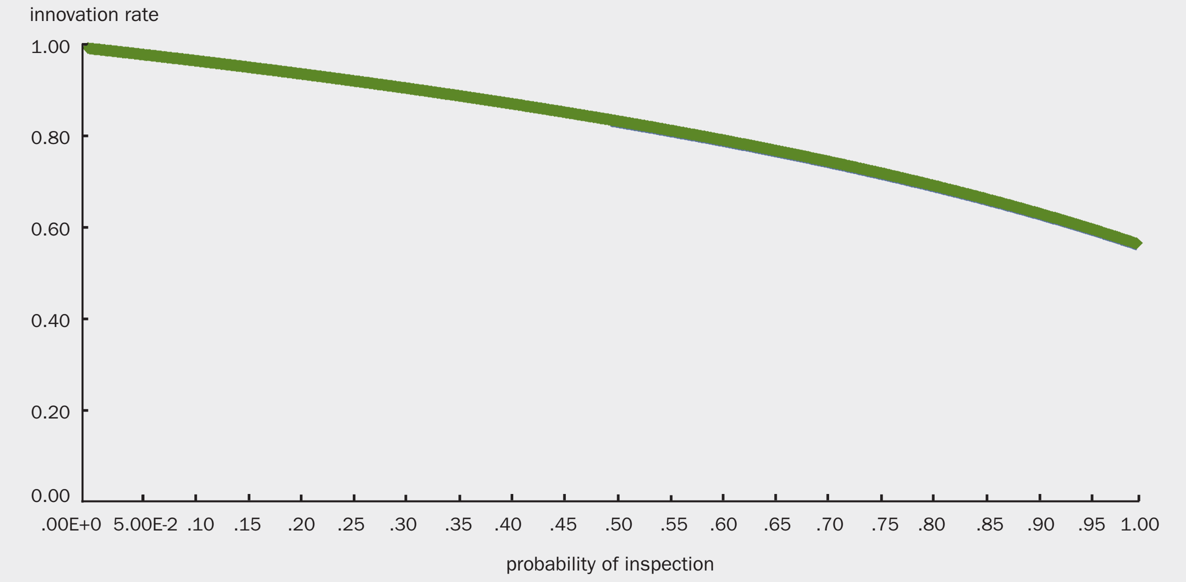


FIGURE A2

Innovation rate (η^*) vs. probability of inspection (γ)



purposes only. The example considered has the following parameter values: $\xi = 0.5$, $\gamma = 0.1$, $\varphi = 0.5$, $p = 0.8$, $m = 0$, $i = 0.04$, $\Pi = 1$ (this is just a normalization), and $r(\eta) = \frac{1}{2}\eta^2$.

Fixing all other parameters at their benchmark values, figure A1 shows how the equilibrium innovation rate depends on the probability of detecting corruption φ. The figure shows that a higher detection probability φ (weakly) increases the innovation rate of the industry. However, the dependence is discontinuous, and once the arrival rate jumps, it is unresponsive to further increases in φ. These properties are general. We see from equations A1 and A2 that $\bar{N}_j(\eta)$ increases with φ when $j = 2$ but is independent of φ when $j = 1$. Moreover, an increase in φ can bring the economy from parameter region $j = 2$ to $j = 1$, entailing a jump in the arrival rate from η_2^* to η_1^* at the critical value for φ at which

$$p + m = \frac{(1-\varphi)}{\varphi}.$$

Figure A2 shows how the equilibrium innovation rate depends on the probability of inspection γ. The figure shows that a higher probability of inspection γ decreases the innovation rate of the industry in a continuous way. This is a general result. We see from equations A1 and A2 that $\bar{N}_j(\eta)$ decreases with γ in each case $j = 1, 2$. Since the functions depicted in figure 5 (p. 34) shift down as γ increases, the intersections with $r'(\eta)$ take place at lower values of η_j^*, for each $j = 1, 2$. However, changes in γ have no effect on the parameter region that the economy lies on. Thus, while the innovation rate decreases with γ, there are no points of discontinuity.

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