protected sugar beet seedlings from infection by *R. solani* (fig. S7). Random transposon mutagenesis generated two mutants of strain SH-C52 with no in vitro activity against *R. solani*. The single transposon insertions were mapped to a nonribosomal peptide synthetase (NRPS) gene with 69% sequence identity to *syrE*, the gene of the syringomycin-syringopeptin (*syr-syp*) biosynthetic pathway in *Pseudomonas syringae* pv. *syringae* (*9*). NRPS-mutant O33 colonized the rhizosphere to the same extent as its parental strain SH-C52, but did not protect sugar beet seedlings from fungal infection (fig. S7). Subsequent genetic analyses revealed that the putative biosynthetic pathway consisted of two gene clusters, designated *thaAB* and *thaC1C2D*, which were predicted to encode a nine–amino acid chlorinated lipopeptide (fig. S8).

The multifaceted approach adopted in this study, linking culture-independent and culture-dependent analyses, shows that plants, like mammals and insects (*10*–*12*), can rely on specific constituents of the microbial community for protection against pathogen infections. We showed that the γ-Proteobacteria, and specifically members of the Pseudomonadaceae, protect plants from fungal infection through the production of a putative chlorinated lipopeptide encoded by NRPS genes. Functional analysis further revealed a significant difference in plant disease suppression between haplotypes SH-A and SH-C (fig. S7), suggesting that in situ antifungal activity is governed by individual members of this bacterial taxon. Next to the Pseudomonadaceae, several other bacterial taxa were found in this study to be associated with disease suppressiveness (Fig. 3). Some of these taxa, including the Burkholderiaceae, Xanthomonadales, and Actinobacteria, harbor genera and species with activity against plant pathogenic fungi, including *R. solani* (*13*). These findings suggest that the complex phenomenon of disease suppressiveness of soils cannot simply be ascribed to a single bacterial taxon or group, but is most likely governed by microbial consortia. The observation that bacterial strains, which lack activity against pathogens when tested alone, can act synergistically when part of microbial consortia (*14*) further exemplifies the complexity of adopting Koch's postulates for identification of microorganisms involved in disease suppressiveness of soils. The bacteria and biosynthetic pathway identified here provide a set of microbial and genetic markers to elucidate whether and how plants recruit beneficial soil microorganisms for protection against infections.

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Supporting Online Material

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Materials and Methods
Figs. S1 to S8
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Differences Between Tight and Loose Cultures: A 33-Nation Study

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With data from 33 nations, we illustrate the differences between cultures that are tight (have many strong norms and a low tolerance of deviant behavior) versus loose (have weak social norms and a high tolerance of deviant behavior). Tightness-looseness is part of a complex, loosely integrated multilevel system that comprises distal ecological and historical threats (e.g., high population density, resource scarcity, a history of territorial conflict, and disease and environmental threats), broad versus narrow socialization in societal institutions (e.g., autocracy, media regulations), the strength of everyday recurring situations, and micro-level psychological affordances (e.g., prevention self-guides, high regulatory strength, need for structure). This research advances knowledge that can foster cross-cultural understanding in a world of increasing global interdependence and has implications for modeling cultural change.

How "other" cultures differ from one's own has piqued the curiosity of scholars and laypeople across the centuries. As long ago as 400 B.C.E., Herodotus documented a wide variety of cultural practices that he observed in his travels in *The Histories* (*1*). Only in the past few decades have scientists begun to move beyond descriptive accounts of cultural differences to empirically assess ways in which national cultures vary. We examine a neglected source of cultural variation that is dominating the geo-political landscape and has the potential to be a major source of cultural conflict: the difference between nations that are "tight"—have strong norms and a low tolerance of deviant behavior—and those that are "loose"—have weak norms and a high tolerance of deviant behavior.

Early anthropological research showed the promise of this distinction. In his study of 21 traditional societies, Pelto (*2*) documented wide variation in the expression of and adherence to social norms. The Hutterites, Hanno, and Lubara were among the tightest societies, with very strong norms and severe sanctions for norm violation, whereas the Kung Bushman, Cubeo, and the Skolt Lapps were among the loosest societies, with ambiguous norms and greater permissiveness for norm violation. Pelto speculated that these societies may have different ecologies, with tight societies having a higher population per square mile and a higher dependence on crops as compared to loose societies. Later research indeed showed that agricultural societies (e.g., the Temne of Sierra Leone), which require strong norms to foster the coordination necessary to grow crops for survival, had strict child-rearing practices and children who were high

on conformity. Hunting and fishing societies (e.g., the Inuit) had lenient child-rearing practices and children who were low on conformity (*3*, *4*).

Despite evidence of the importance of this contrast in traditional societies, there exists no insight into how tightness-looseness operates in modern nations. The goal of this research is to fill this void. Drawing on theorizing in cultural psychology (*5*, *6*), we propose that tightness-looseness is part of a complex, loosely integrated system that involves processes across multiple levels of analysis (Fig. 1). We theorize that the strength of social norms and tolerance of deviant behavior—the core distinction between tight and loose cultures—is afforded by numerous distal ecological and human-made societal threats and societal institutions and practices. The strength of social norms and tolerance of deviant behavior is further reflected and promoted in the predominance of strong versus weak situations that are recurrent in everyday local worlds, and is reinforced through psychological processes that are attuned to situational requirements. We provide an empirical test that shows how ecological, historical, and institutional factors, along with everyday situations and psychological processes, together constitute cultural systems.

We predict that tightness-looseness is afforded by a broad array of ecological and human-made societal threats (or lack thereof) that nations have historically encountered (*4*, *7*). Ecological and human-made threats increase the need for strong norms and punishment of deviant behavior in the service of social coordination for survival—whether it is to reduce chaos in nations that have high population density, deal with resource scarcity, coordinate in the face of natural disasters, defend against territorial threats, or contain the spread of disease. Nations facing these particular challenges are predicted to develop strong norms and have low tolerance of deviant behavior to enhance order and social coordination to effectively deal with such threats. Nations with few ecological and human-made threats, by contrast, have a much lower need for order and social coordination, affording weaker social norms and much more latitude (*8*).

The strength of social norms and tolerance of deviant behavior is also afforded by and reflected in prevailing institutions and practices. Institutions in tight nations have narrow socialization that restricts the range of permissible behavior, whereas institutions in loose nations encourage broad socialization that affords a wide range of permissible behavior (*9*). Relative to loose nations, tight nations are more likely to have autocratic governing systems that suppress dissent, to have media institutions (broadcast, paper, Internet) with restricted content and more laws and controls, and to have criminal justice systems with higher monitoring, more severe punishment (e.g., the death penalty), and greater deterrence and control of crime. Tight nations will also be more religious, thereby reinforcing adherence to moral conventions and rules that can facilitate social order and coordination (*10*). Challenges to societal institutions (e.g., demonstrations, boycotts, strikes) will be much less common in tight nations than in loose ones. These institutions and practices simultaneously reflect and support the strength of norms and tolerance of deviance that exists in nations.

Tightness-looseness is manifested not only in distal ecological, historical, and institutional contexts but also in everyday situations in local worlds (e.g., at home, in restaurants, classrooms, public parks, libraries, the workplace) that individuals inhabit (*5*, *6*). We theorize that tightness-looseness is reflected in the predominance of strong versus weak everyday situations (*11*, *12*). Strong situations have a more restricted range of appropriate behavior, have high censuring potential, and leave little room for individual discretion. Weak situations place few external constraints on individuals, afford a wide range of behavioral options, and leave much room for individual discretion. Situational strength has been long discussed among psychologists, sociologists, and anthropologists (*11*–*14*) but has yet to be linked to cultural variation. Tight nations are expected to have a much higher degree of situational constraint which restricts the range of behavior deemed appropriate across everyday situations (e.g., classrooms, libraries, public parks, etc.). By contrast, loose nations are expected to have a much weaker situational structure, affording a much wider range of permissible behavior across everyday situations. The strength (or weakness) of everyday recurring situations within nations simultaneously reflects and supports the degree of order and social coordination in the larger cultural context.

We further theorize that there is a close connection between the strength (versus weakness) of everyday situations and the chronic psychological processes of individuals within nations. In this view, individuals' psychological processes become naturally attuned to, and supportive of, the situational demands in the cultural system (*15*). Individuals who are chronically exposed to stronger (versus weaker) situations in their everyday local worlds have the continued subjective experience that their behavioral options are limited, their actions are subject to evaluation, and there are potential punishments based on these evaluations. Accordingly, individuals in nations with high situational constraint will have self-guides that are more prevention-focused (*16*) and thus will be more cautious (concerned with avoiding mistakes) and dutiful (focused on behaving properly), and will have higher self-regulatory strength (higher impulse control) (*17*), a higher need for structure (*18*), and higher self-monitoring ability (*19*, *20*). Put simply, the higher (or lower) degree of social regulation that exists at the societal level is mirrored in the higher (or lower) amount of self-regulation at the individual level in tight and loose nations, respectively. Such psychological processes simultaneously reflect and support the strength of social norms and tolerance of deviance in the larger cultural context.

To provide a systematic analysis of tightness-looseness in modern societies, we gathered data

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from 6823 respondents across 33 nations (*20*). Sample characteristics are shown in Table 1 (*21*). In each nation, we surveyed individuals from a wide range of occupations as well as university students. Data on ecological and historical threats and societal institutions were collected from numerous established databases (*20*). When possible, historical data were included (e.g., population density in 1500, history of conflict 1918–2001, historical prevalence of pathogens).

Tightness-looseness (the overall strength of social norms and tolerance of deviance) was measured on a six-item Likert scale that assessed the degree to which social norms are pervasive, clearly defined, and reliably imposed within nations. Example scale items include "There are many social norms that people are supposed to abide by in this country," "In this country, if someone acts in an inappropriate way, others will strongly disapprove," and "People in this country almost always comply with social norms." The results show strong support for the reliability and validity of the measure (*20*). Ecological factor analyses and Procrustes factor analysis in all 33 nations illustrate that the scale exhibits factor validity and measurement equivalence. Analyses show that the strength of social norms and tolerance of deviance is a shared collective construct: There is high within-nation agreement in each nation [$r_{\text{within-group}}(M)$ = 0.85], high between-nation variability [$F(32, 6{,}774) = 31.23$, $P < 0.0001$; intraclass correlation (ICC)(1) = 0.13], and high reliability of the tightness-looseness scale means [ICC(2) = 0.97]. The scale has high convergent validity with expert ratings, unobtrusive measures, and survey data from representative samples; is able to adequately discriminate between cultural regions; and is distinct from other cultural dimensions (*20*) (tables S1 and S2).

The degree of constraint across a wide range of everyday social situations was measured through adaptations to Price and Bouffard's established measure (*20*). Participants rated the appropriateness of 12 behaviors (i.e., argue, eat, laugh, curse/swear, kiss, cry, sing, talk, flirt, listen to music, read newspaper, bargain) across 15 situations (i.e., bank, doctor's office, job interview, library, funeral, classroom, restaurant, public park, bus, bedroom, city sidewalk, party, elevator, workplace, movies), resulting in a total of 180 behavior-situation ratings (*20*). For a given situation, the mean appropriateness ratings across behaviors indicate the degree of situational constraint: Low values indicate that there are few behaviors considered appropriate in that situation, whereas high values indicate that a wide range of behaviors are considered appropriate in that situation. Country-level scores of situational constraint were derived by averaging scores across situations. Analyses illustrate that the situational constraint measure is a shared collective construct within nations (*20*): There is high within-nation agreement about the level of constraint in everyday situations in each nation [$r_{\text{within-group}}(M) = 0.99$], high between-nation variability in situational constraint [$F(32, 6790) = 92.9$, $P < 0.0001$; ICC(1) = 0.31], and high reliability of the situational constraint means [ICC(2) = 0.99]. There is strong construct validity of the measure (*20*). Respondents in each nation also provided direct ratings regarding whether the 15 situations had clear rules for appropriate behavior, called for certain behaviors and not others, required people to monitor their behavior or "watch what they do," and allowed individuals to choose their behavior (reverse-coded), the average of which is highly correlated with the behavior-situation ratings ($r = 0.74$, $P < 0.001$). The correlation of the current situational constraint data in the United States with those reported by Price and Bouffard is 0.92 ($P < 0.001$) (*20*), which suggests that the degree of constraint across situations is generally stable across time.

Psychological processes (prevention focus, self-regulation strength, need for order, self-monitoring) were assessed with well-validated measures (*20*). Procrustes factor analysis of all of the measures across the 33 nations all evidenced high equivalence and high degrees of cross-national variation (*20*).

To test our predictions, we first examine the relationships between tightness-looseness and ecological and historical institutions. Because many of these variables are associated with national wealth, we controlled for nations' GNP per capita to examine their unique relationships with tightness-looseness. We next illustrate how tightness-looseness is related to the strength of everyday situations and examine the cross-level relationship between the strength of situations and numerous psychological processes with the use of hierarchical linear modeling. We provide a test of the overall model with multilevel structural equation analysis (*20*).

Table S3 illustrates that nations that have encountered ecological and historical threats have much stronger norms and lower tolerance of deviant behavior. Tight nations have higher population density in the year 1500 ($r = 0.77$, $P = 0.01$), in the year 2000 in the nation ($r = 0.31$, $P = 0.10$), and in the year 2000 in rural areas ($r = 0.59$; $P = 0.02$), and also have a higher projected population increase ($r = 0.40$, $P = 0.03$). Tight nations have a dearth of natural resources, including a lower percentage of farmland ($r = -0.37$, $P = 0.05$), higher food deprivation ($r = 0.52$, $P < 0.01$), lower food supply and production ($r = -0.36$, $P = 0.05$, and -0.40, $P = 0.03$, respectively), lower protein and fat supply (rs = -0.41 and -0.46, Ps = 0.03 and 0.01), less access to safe water ($r = -0.50$, $P = 0.01$), and lower air quality ($r = -0.44$, $P = 0.02$), relative to loose nations. Tight nations face more disasters such as floods, tropical cyclones, and droughts ($r = 0.47$, $P = 0.01$) and have had more territorial threats from their neighbors during the period 1918–2001 ($r = 0.41$, $P = 0.04$). Historical prevalence of pathogens was higher in tight

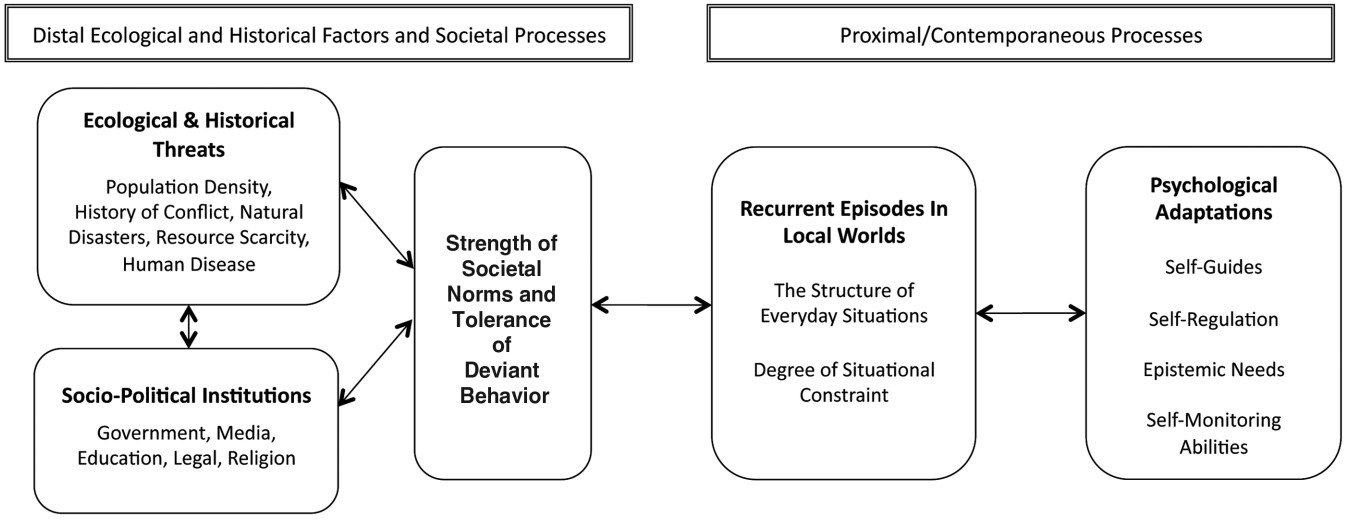

Fig. 1. A systems model of tightness-looseness.

nations ($r = 0.36$, $P = 0.05$), as were the number of years of life lost to communicable diseases ($r = 0.59$, $P < 0.01$), the prevalence of tuberculosis ($r = 0.61$, $P < 0.01$), and infant and child mortality rates (rs = 0.42, $P = 0.02$, and 0.46, $P = 0.01$).

Tightness-looseness is reflected in societal institutions and practices (table S3). Tight nations are more likely to have autocratic rule that suppresses dissent ($r = 0.47$, $P = 0.01$), less open media overall ($r = -0.53$, $P < 0.01$), more laws and regulations and political pressures and controls for media (rs = 0.37 to 0.62, Ps ≤ 0.05), and less access to and use of new communication technologies ($r = -0.38$, $P = 0.04$). Tight nations also have fewer political rights and civil liberties (rs = –0.50 and –0.45, Ps ≤ 0.01). Criminal justice institutions in tight nations are better able to maintain social control: There are more police per capita ($r = 0.31$, $P = 0.12$), stricter punishments (i.e., retention of the death penalty) ($r = 0.60$, $P < 0.01$), and lower murder rates and burglary rates (rs = –0.45 and –0.47, Ps < 0.01) and overall volume of crime ($r = -0.37$, $P = 0.04$). Tight nations are more religious, with more people attending religious services per week ($r = 0.54$, $P < 0.01$) and believing in the importance of god in life ($r = 0.37$, $P < 0.05$) (*20*). The percentage of people participating in collective actions (e.g., signing petitions, attending demonstrations) is much lower in tight nations ($r = -0.40$, $P = 0.03$), and more people report that they would never engage in such actions ($r = 0.36$, $P = 0.05$) in comparison to loose nations.

Tightness-looseness is also related to the strength of everyday recurring situations within nations. As predicted, there is much higher situational constraint in tight versus loose nations ($r = 0.55$, $P < 0.01$) (*22*). In other words, there is much higher constraint across everyday situations—including the bank, public park, library, restaurant, bus, workplace, party, classroom, and the like—in tight nations, and much lower constraint across such everyday situations in loose nations (*20*). Hierarchical linear modeling intercept-as-outcomes models showed that higher levels of situational constraint are significantly related to greater prevention self-guides [higher cautiousness: $\gamma_{01} = 1.48$, $t(31) = 7.54$, $P < 0.01$; higher dutifulness: $\gamma_{01} = 1.11$, $t(31) = 5.05$, $P < 0.01$], greater self-regulation strength [higher impulse control: $\gamma_{01} = 1.18$, $t(31) = 6.60$, $P < 0.01$], higher needs for structure [$\gamma_{01} = 2.67$, $t(31) = 5.76$, $P < 0.01$], and higher self-monitoring [$\gamma_{01} = 0.94$, $t(31) = 3.69$, $P < 0.01$] (*23*). This suggests that societal members' psychological characteristics are attuned to and supportive of the degree of constraint versus latitude in the larger cultural context. Multilevel structural equation analyses that simultaneously tested the proposed relations in Fig. 1 illustrated very good fit to the data (*20*).

In all, the data illustrate that tightness-looseness, a critical aspect of modern societies that has been heretofore unexplored, is a part of a

Table 1. Sample characteristics of the 33 nations.

Nation	Data collection site(s)	Language of survey	Number of participants	Mean age (±SD)	Percentage female	Percentage students	Tightness score
Australia	Melbourne	English	230	25.4 ± 10.0	69.1	63.9	4.4
Austria	Linz	German	194	31.6 ± 11.8	51.5	41.8	6.8
Belgium	Leuven (Flanders region)	Dutch	138	33.3 ± 14.3	73.2	50.7	5.6
Brazil	São Paulo	Portuguese	196	27.5 ± 9.4	72.3	40.3	3.5
Estonia	Tartu	Estonian	188	32.0 ± 16.8	86.6	52.1	2.6
France	Paris, Cergy	English	111	25.2 ± 4.1	37.8	67.6	6.3
Germany (former East)	Chemnitz	German	201	31.6 ± 12.2	66.7	49.3	7.5
Germany (former West)	Rhineland-Palatine/Frankfurt	German	312	32.5 ± 14.5	63.8	51.6	6.5
Greece	Athens	Greek	275	30.9 ± 11.3	56.7	45.1	3.9
Hong Kong	Hong Kong	Chinese	197	27.3 ± 11.7	68.0	53.8	6.3
Hungary	Budapest, Szeged	Hungarian	256	30.8 ± 10.9	42.2	48.0	2.9
Iceland	Reykjavík	Icelandic	144	36.3 ± 13.3	67.4	41.7	6.4
India	Ahmedabad, Bhubneswar, Chandigarh, Coimbatore	Hindi	222	27.8 ± 9.6	54.1	52.3	11.0
Israel	Tel-Aviv, Ramat-Gan, Jerusalem, Petach-Tikva	Hebrew	194	30.2 ± 10.7	60.3	48.5	3.1
Italy	Padova	Italian	217	29.6 ± 10.3	40.1	53.0	6.8
Japan	Tokyo, Osaka	Japanese	246	33.2 ± 14.9	55.7	48.8	8.6
Malaysia	Bandar Baru Bangi	Malay	202	29.5 ± 9.1	49.5	45.0	11.8
Mexico	Mexico City	Spanish	221	27.7 ± 11.6	42.1	40.3	7.2
Netherlands	Groningen	Dutch	207	29.8 ± 11.9	55.6	53.1	3.3
New Zealand	Wellington	English	208	29.9 ± 13.0	64.4	61.1	3.9
Norway	Bergen	Norwegian	252	31.8 ± 11.0	56.7	46.0	9.5
Pakistan	Hyderabad	Urdu	190	30.0 ± 9.8	51.1	52.6	12.3
People's Republic of China	Beijing	Chinese	235	29.4 ± 11.5	45.9	53.2	7.9
Poland	Warsaw	Polish	210	28.5 ± 12.4	65.2	51.9	6.0
Portugal	Braga	Portuguese	207	28.5 ± 11.6	54.6	58.0	7.8
Singapore	Singapore	English	212	26.1 ± 6.7	59.0	49.1	10.4
South Korea	Seoul	Korean	196	26.2 ± 7.5	61.2	73.5	10.0
Spain	Valencia	Spanish	172	30.2 ± 9.6	66.9	40.1	5.4
Turkey	Istanbul	Turkish	195	32.0 ± 14.4	53.3	45.6	9.2
Ukraine	Odessa	Ukrainian	184	30.8 ± 12.7	56.5	44.6	1.6
United Kingdom	Brighton	English	185	29.9 ± 11.5	67.0	51.4	6.9
United States	Washington, DC; Maryland; Virginia	English	199	31.4 ± 13.7	60.3	48.2	5.1
Venezuela	Caracas	Spanish	227	35.8 ± 10.0	60.4	1.3	3.7
Totals/means			**6823**	**30.1 ± 11.3**	**58.6**	**49.2**	**6.5**

system of interrelated distal and proximal factors across multiple levels of analysis. In addition to explicating how tight and loose cultures vary in modern societies, this research has implications for understanding and modeling how tight and loose cultures are maintained and changed. Substantial top-down or bottom-up changes in any of the levels in the model may trigger a rippling effect to other levels, resulting in changes in tight or loose cultures.

As culture is fundamentally a system, causal inferences regarding the direction of the relationships need further examination, particularly given that they are likely reciprocal. Future research should also apply the basic principles of the current work to explore variation in tightness-looseness at other levels of analysis (e.g., regions).

We also note that the samples in this study are not representative of each nation. However, the diverse backgrounds of the participants, high agreement among different subgroups, and correlations with other measures drawn from representative samples lend confidence to the generalizability of the results (*20*).

This research illuminates the multitude of differences that exist across tight and loose cultures. From either system's vantage point, the "other system" could appear to be dysfunctional, unjust, and fundamentally immoral, and such divergent beliefs could become the collective fuel for cultural conflicts. Indeed, as Herodotus (*1*) remarked centuries ago, "if one were to order all mankind to choose the best set of rules in the world, each group would, after due consideration, choose its own customs; each group regards its own as being the best by far" (p. 185). Such beliefs fail to recognize that tight and loose cultures may be, at least in part, functional in their own ecological and historical contexts. Understanding tight and loose cultures is critical for fostering cross-cultural coordination in a world of increasing global interdependence.

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22. For ease of interpretation, the situational constraint score was reversed such that high values are indicative of higher constraint.
23. We also ran these analyses with a split-sample approach (*25*) to eliminate single-source bias as an alternative explanation for our findings. Within each country we randomly assigned participants to one of two groups: One group provided the situational constraint scores and the other group provided the individual-difference scales. These hierarchical linear modeling results were the same as with the full sample.
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Supporting Online Material

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References

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