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Historical prevalence of infectious diseases and sustainable development in 122 countries

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Abstract

This study investigates the effects of historical prevalence of infectious diseases on contemporary sustainable development. Previous studies reveal numerous proximate causes of sustainable development, but little is known about the fundamental determinants of this widespread economic concern. The novelty of this paper lies in the adoption of a historical approach that sheds light on the deep historical roots of cross-country differences in sustainable development. The central hypothesis is that historical pathogens exert persistent impacts on present-day sustainable development. Using Ordinary Least Squares (OLS) and Two Stage Least Squares (2SLS) in cross-section with data from 122 countries between 2000 and 2021, we provide support for the underlying hypothesis. Past diseases reduce sustainable development both directly and indirectly. The strongest indirect effects occur through property rights, innovation, globalization and government effectiveness. This result is robust

1 The views expressed in this working paper are those of the authors and do not necessarily represent those of the ASPROWORDA, its Executive Board, or its management.

to many sensitivity tests. Policy makers may take these findings into account and incorporate disease pathogens into the design of international sustainable development.

Keywords**:** infectious diseases; sustainable development, economic development

JEL Classification: B15; B40; I31; J24; Q01

1. Introduction

The motivation of this study builds on two main strands in the policy and scholarly literature, notably: the historical prevalence of infectious diseases on sustainable development and gaps in the literature. These strands are chronologically discussed. First, regional differences in infectious diseases and disease prevalence are linked to a range of cross-cultural differences. Nevertheless, the complexity of relationships between disease, culture and other factors which have an impact on sustainable development remain under-investigated (Murray & Schaller, 2010). The authors developed an index based on disease prevalence data derived from old epidemiological atlases, which is computed from 230 geopolitical regions worldwide. More recently, Nikolaev and Salahodjaev (2017) have shown that some determinants of economic institutions such as the banking system, competitive markets and the property rights structure are essential factors of economic development. However, these economic institutions vary across countries and the sources of their origins are still widely debated in the literature related to economic development in particular and sustainable development in general. The underlying authors have provided an empirical testable hypothesis stating that the formation of personality traits, morality at the regional level (what is commonly called the Parasite-Stress Theory of Values and Sociality) and even the cultural values are influenced by the prevalence of infectious diseases. Nikolaev and Salahodjaev (2017) equally noted that, these factors shaped the structure of institutions at the economic level and across countries.

Second, we also engage different empirical exercises to test methods applied in seminal papers such as Zhao *et al*. (2010), Baron and Kenny (1986) and Anderson and Rubin (1949) in order to confirm our main hypothesis which states that: historical prevalence of disease pathogen reduces sustainable development. We therefore contribute to the extant literature on with a perspective of a nexus between historical prevalence of infectious disease and sustainable development. The attendant literature includes; Bennett and Nikolaev (2021); Hill *et al*. (2016); Nikolaev *et al*. (2017); Thornhill *et al*. (2009); Thornhill and Fincher (2014) and Varnum and Grossmann (2017).

The rest of this paper is structured as follows. The theoretical underpinnings and stylized facts are covered in Section 2 while Section 3 presents the main empirical method, data and the corresponding sources. The choice of the main variables and different channels are also discussed using empirical literature. Section 4 presents the results and discussion while Section 5 provides potential channels linking disease prevalence to sustainable development using empirical tests and literature. Section 6 concludes with recommendations and directions for future research.

2. Disease pathogen and sustainable development: theoretical background

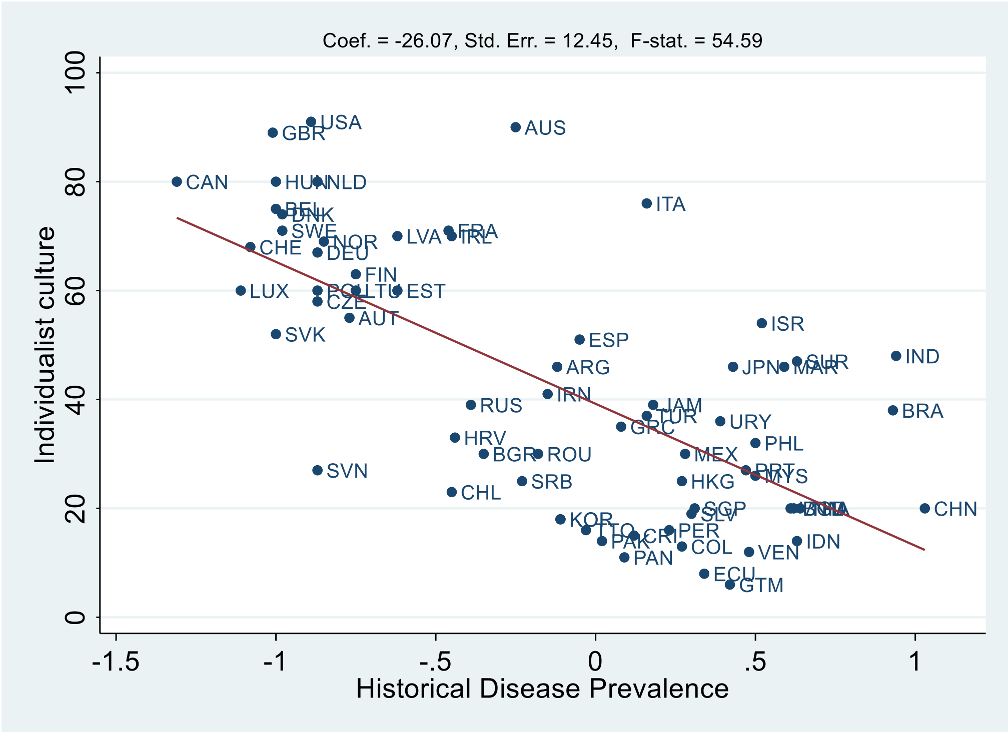
Stylized facts and theoretical underpinnings underlying the nexus between disease pathogen and sustainable development are broadly consistent with Omang *et al*. (2022) on the nexus between disease pathogen and gender equality, granting that gender inclusion is a dimension of sustainable development. The association between gender inclusion and sustainable development is consistent with Amavilah *et al*. (2017) on the nexus between inclusive development and sustainable development. According to Amavilah *et al*. (2017), in order for inclusive development to be sustainable development, it should be sustained and in order for sustained development to be sustainable, it must be inclusive.

In the light of the above, the relevance of theoretical underpinnings and sustainable development fundamentally draws on the parasite stress theory of economic development (Schaller & Murray, 2008; Thornhill *et al*., 2009; Murray & Schaller, 2010; Murray et al., 2011, 2013; Fincher *et al*., 2013; Thornhill & Fincher, 2014; Randy Thornhill & Fincher, 2011, 2014; Bennett & Nikolaev, 2021; Omang *et al*., 2022). In accordance with the attendant theory, the nexus between non-contemporary diseases and contemporary development outcomes is premised on the following channels, *inter alia*, political regime, innovation and culture. These channels are substantiated in what follows.

First, with respect to the cultural mechanism, disparities between communities, especially with respect to parasitic stress provides avenues for the distinction between collectivist and individualistic societies. Within the remit of collectivist societies, an important border is apparent to distinguish between a group of non-membership and a group of belonging. Within this framework, one group expresses suspicion about members of the group. Conversely, in societies that are individualistic, the underlying characteristic is not very apparent, not least, because there is a high probability of contact between elements of society

(Sagiv & Schwartz, 1995; Gelfand *et al*., 2004; Omang *et al*., 2022). As articulated by Thornhill and Fincher (2014), conservative (collectivist) societies give preference to within-growth alliance whereas liberal (individualist) societies instead favour nexuses with groups from other societal classes.

Figure 1 : Historical prevalence of infectious disease and individualist culture



Source: authors' construction; ***Notes:*** The scatter plots in the above figure illustrate a negative relationship between Historical prevalence of infectious disease and individualist culture. Their correlation coefficient is -26.07. The total number of observations is 122.

According to the attendant literature (Thornhill & Fincher, 2014; Omang *et al*., 2022), low prevalence of infectious diseases are linked to environments in which an individualistic cultures is prevalent, notably, in societies in which people are expected to be responsible for taking care of themselves as well as their immediate family members. In essence, these societies are characterised by distinctions in the valuation of equality of class, opportunity, personal achievement, individual freedoms, knowledge and progress. Conversely, in societies where the collectivist culture is prevalent, the contamination rate of diseases is quite high because from birth, the population is integrated into a cohesive and strong group in which loyalty is traded for insurance of safety (Omang *et al*., 2022). In effect, more value is attributed to qualities such as cooperation, harmony and the nexus with the superior fraction of society which has consequences in income inequality and by extension, sustainable development prospects. In essence, concerns about sustainable development can be less raised by the lower classes of society owing to an established hierarchical distance. Figure 1 illustrates the negative nexus between historical prevalence of infectious disease and individualist culture.

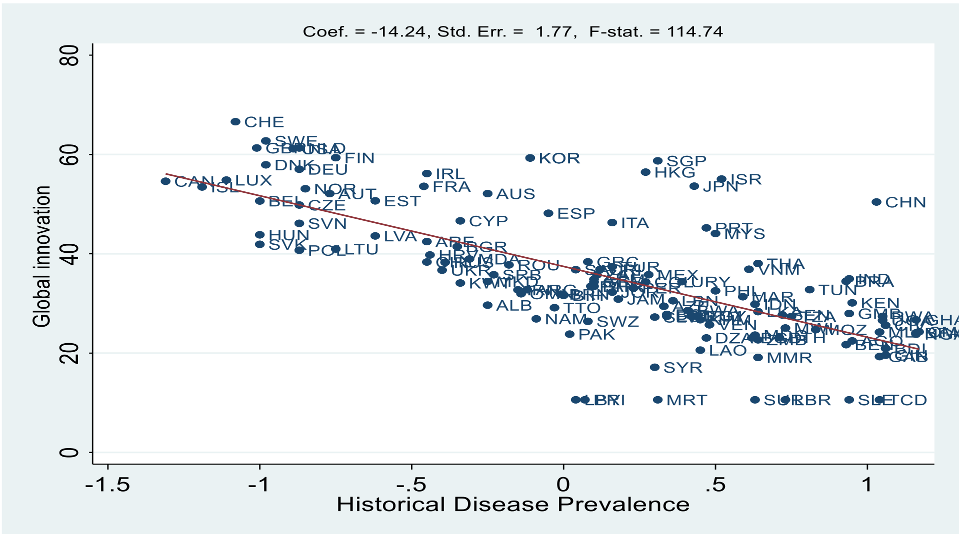
Second, institutions (democracy versus autocracy) have also been documented as a mechanism by which the historical prevalence of diseases influences contemporary economic development outcomes, such as sustainable development that is considered within the remit of the present study (Thornhill *et al*., 2009; Omang *et al*., 2022). With respect to Thornhill *et al*. (2009), the process of democratization which fundamentally builds on individualism, substantially improves features of liberalization that are more apparent in ecological conditions characterized by low prevalence of disease stress. The underlying therefore, provides favorable avenues along which expressions in favour of inclusive and sustainable development can be more openly made (Wejnert, 2005; Omang *et al*., 2022).

It is important to note that, inclusive and by extension sustainable development, is less apparent within collectivist societies. In follows that democratic values are more likely to evolve from individualistic cultures and by extension, represent less of an obstacle to economic development outcomes such as sustainable development, not least, because democratic values provide more avenues for the promotion of sustainable development values such as inclusive growth and environmental protection. On the contrary, as argued by the corresponding literature (Gelfand *et al*., 2004; Omang *et al*., 2022), collectivist societies are negatively linked to sustainable and inclusive development outcomes. Moreover, democracy which is also more linked to inclusive development outcomes is also more associated with an individualistic culture which has less nexuses with an environment of epidemic. Conversely, as Omang *et al*. (2022) have argued that an ideology of autocracy is linked to conservatism and exclusive development which are more connected to an environment with parasitic stress. In the light of this logic, according to Schaller and Murray (2008), cultural norms are positively affected by parasitic stress. Hence, the variation in infectious disease risk that is apparent from both contemporary and non-contemporary perspectives can either be conducive to autocracy or democracy which ultimately affects sustainable development outcomes.

Third, in accordance with the innovation mechanism, innovations promote inclusive and sustainable development (Wrigley, 1992; Keisu, 2013; Saâd & Assoumou-Ella, 2019;

Asongu & Odhiambo, 2019a, 2020; Omang *et al*., 2022). To put this channel in more perspective, it has been established by Bennett and Nikolaev (2021) that an innovation culture is significantly influenced by a diseases environment. According to the narrative, innovation is less associated with a collectivist culture, compared to an individualistic culture. Accordingly, contrary to collectivist societies, individualistic societies encourage independent thinking which is favorable to bold and new ideas (Alesina & Giuliano, 2010; Asongu & Odhiambo, 2019b, 2019c). World innovation is most comprehensively measured by the World Intellectual Property Organization (WIPO) (WIPO, 2021). Figure 2 illustrates the discussed negative nexus between the historical prevalence of infectious diseases and global innovation.

Figure 2: Historical prevalence of infectious disease and global innovation



Source: authors' construction; ***Notes:*** The scatter plots in the above figure illustrate a negative relationship between Historical prevalence of infectious disease and global innovation.

3. Empirical approach

3.1Methodology

The following model is regressed to investigate how sustainable development is related to historical prevalence of infectious diseases in country $\boldsymbol{i}$:

$$Sus\_dev_i = \alpha + \beta.pathogens_i + \sigma.K_i + \varepsilon_i$$

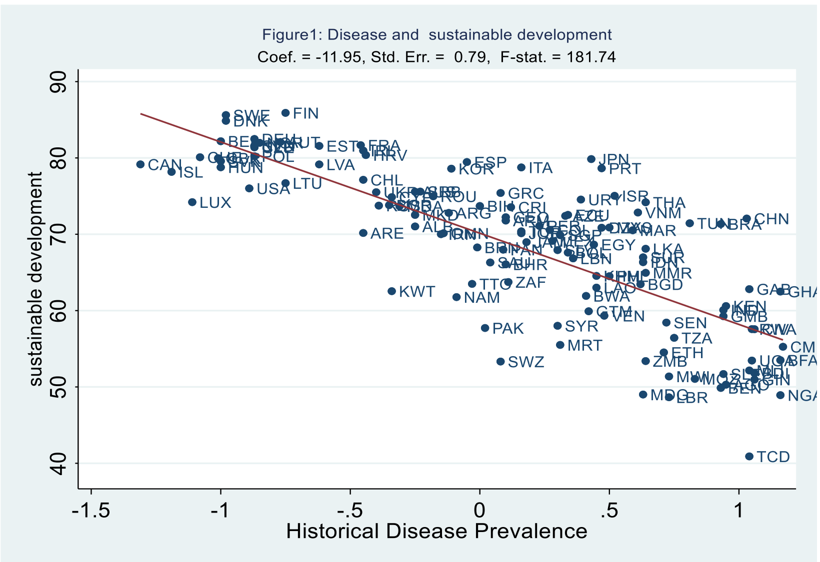
where Sus_dev_i is an indicator of sustainable development (sustainable goals score index) in country $\boldsymbol{i}$; $pathogens_i$ measures the historical prevalence of infectious disease in country $\boldsymbol{i}$;

$\boldsymbol{K_i}$ is a vector of control variables and $\boldsymbol{\varepsilon_i}$ is an unobserved error term. $\boldsymbol{\beta}$ is the coefficient of interest and is expected to carry a negative sign.

3.2 Data

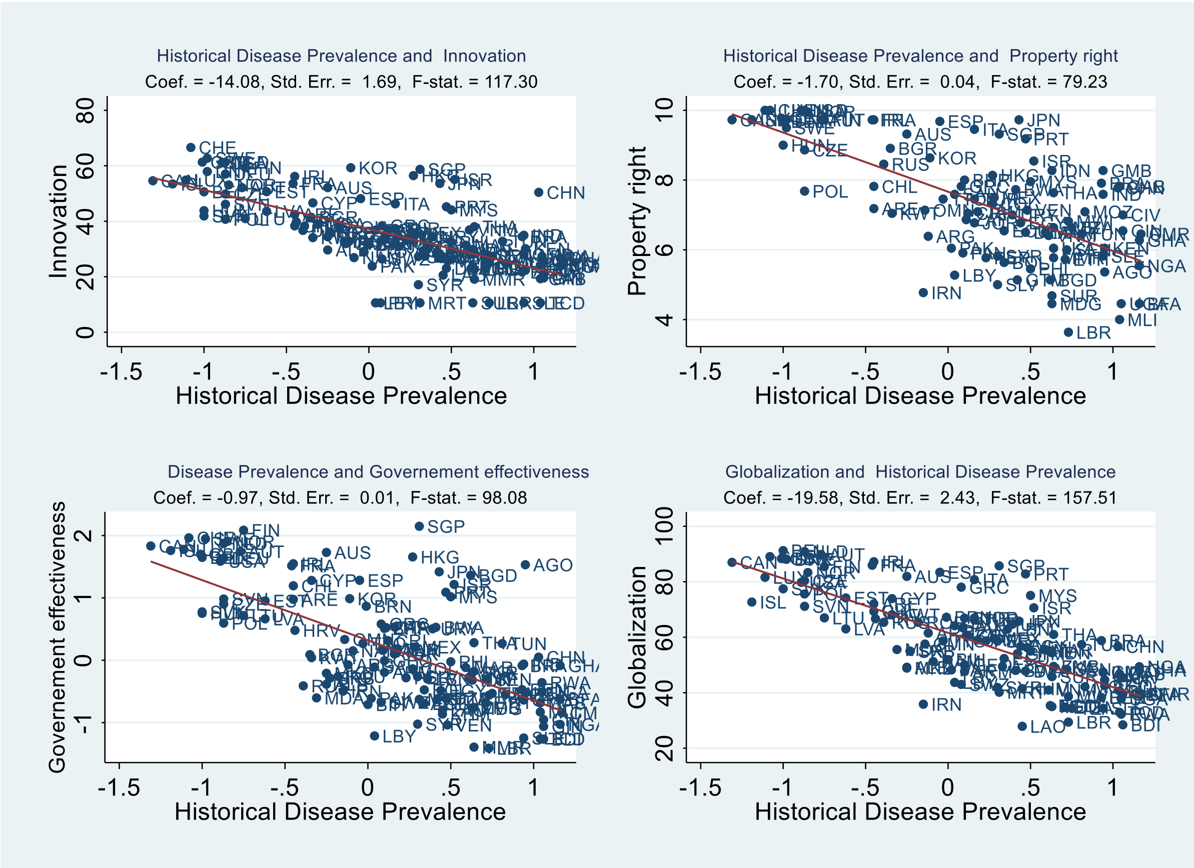
In this sub-section, we discuss the key variables used. Appendix A provides a list of all variables used, summary statistics and data sources. Figure 3 is a scatter plot illustrating the negative reduced-form relationship between historical prevalence of infectious disease and sustainable development for the sample countries. Figure 4 demonstrates a negative relationship between disease pathogen and four variables recognized as the channels through which historical disease persists on sustainable development according to the parasite stress theory (Bennett & Nikolaev, 2021; Hill *et al.*, 2016; Nikolaev, Boris & Salahodjaev, 2017; Thornhill *et al.*, 2009; Thornhill & Fincher, 2014; Varnum, & Grossmann, 2017). This potential channels are: global innovation, property rights, government effectiveness and globalization. Their correlation coefficients are respectively high. This suggests that the historical prevalence of infectious diseases passes through these variables to affect sustainable development. We discuss this claim in more detail in sections 5.1 and 5.2.

Figure 3. Historical prevalence of infectious diseases and sustainable development



Source: authors' construction. ***Notes:*** The scatter plots in the above Figure illustrate a negative relationship between historical prevalence of infectious disease and sustainable development. The total number of observations is 122.

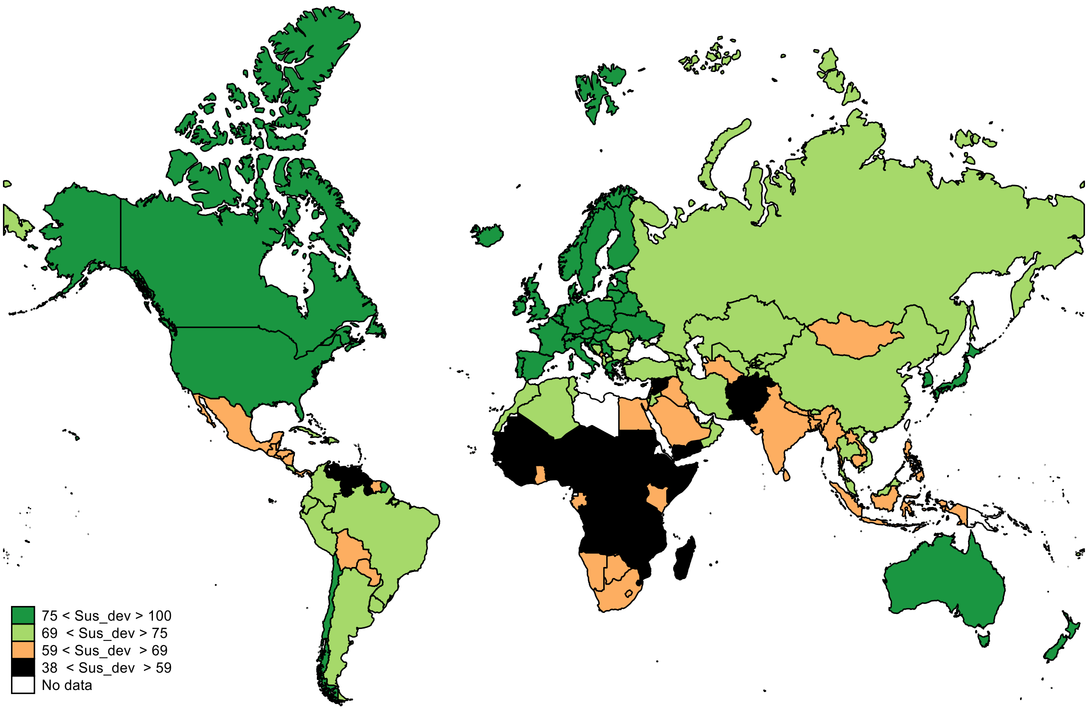
Figure 4. Disease and potential channels



Source: authors' construction; ***Notes:*** The scatter plots in the above figure illustrate a negative relationship between Historical prevalence of infectious disease global innovation; property right; governance effectiveness and globalization.

As stated above, the measure of ***sustainable development*** is the average value of the indicator proposed by Sachs *et al*. (2021) between 2000 and 2021. This indicator is a combination of an assessment of each country's overall performance of the seventeen sustainable development goals (SDGs), giving equal weight to each goal. The combination includes variable such as: no Poverty; Zero Hunger; Good Health and Well-Being; Quality of Education; Gender Equality; Clean Water and Sanitation; Affordable and Clean Energy; Decent Work and Economic Growth; Industry, Innovation and Infrastructure; Reduced Inequalities; Sustainable Cities and Communities; Responsible Consumption and Production; Life Below Water; Life on Land; Peace, Justice and Strong Institutions; Climate Action and Partnerships for the Goals. This variable takes value between 0 (*absence of sustainable development*) and 100 (*high sustainable development*). To test the sensitivity of our results according to the measure of sustainable development, we use two alternative measures of sustainable development. The first one is the index of Lange *et al*. (2019) adopted by the World Bank Group. This index which measures the Adjusted Net Savings, provides national decision makers with a clear, relatively simple indicator on how sustainable a country's investment policies are. This indicator have been used by Koirala (2019) in an empirical analysis of the determinants of sustainable development in 12 Asian countries. The second one is the sustainable development index provided by Hickel (2020) which captures the ecological efficiency of sustainable development.

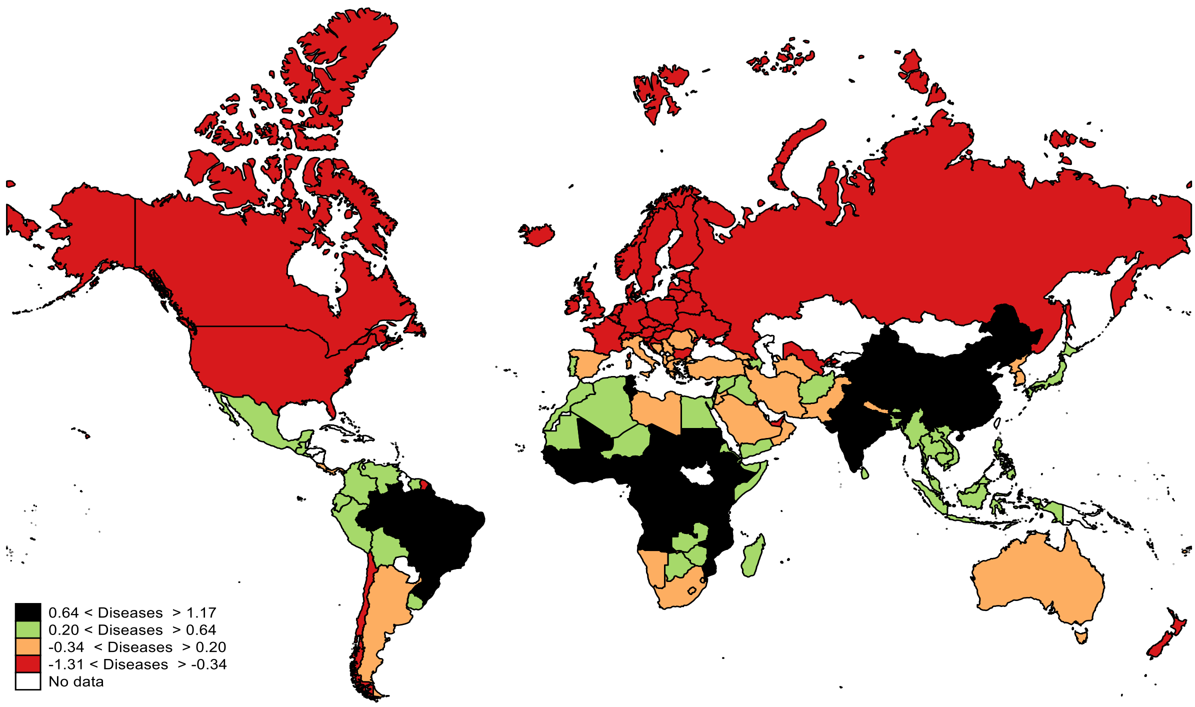
Figure 5. Distribution of sustainable development index around the world



Notes: Black areas indicate bad performance on sustainable development. The total number of observations is 174. The data are obtained from Sachs *et al*. (2021).

The measure of "***historical prevalence of infectious diseases***" is chosen under the inspiration of the vast cross-cultural literature developed by many authors such as Bennett and Nikolaev (2021), Bennett (2019), Bennett (2018), Nikolaev et al. (2017) and Fincher *et al*. (2013). The index used is borrowed from Murray and Schaller (2010). This index assesses the intensity of historical disease prevalence over 150 countries before 1950. The negative value of this index represents the low level of disease prevalence and the positive value the high level of disease prevalence. The calculation of this index is based on the severity of nine diseases dangerous to human survival and reproductive health. These include: dengue, trypanosomes, schistosomes, leprosy, typhus, malaria, filariae, leishmanias, and tuberculosis. It provides evidence for the parasitic stress theory of disease developed by Thornhill and Fincher (2014). It is considering as the best cross country-dataset up-to-date.

Figure 6. Distribution of disease pathogens around the world



Source: *authors' construction.* ***Notes*:** Black areas indicate high prevalence of infectious disease. The total number of observations is 166. The data are obtained from Murray and Schaller (2010).

4. Empirical results and discussion

4.1 Baseline results

The estimation results are presented in Table 1. We consider several alternative specifications to ensure that the results are not driven by any particular model specification. In particular, we include ancestral characteristics of modern population (precolonial institutions; terrain ruggedness ; climate zones and ancestral environment) recognized by Giuliano and Nunn (2018) as strong determinants of development and continent dummies (North America; South Asia; Sub-Saharan Africa; Middle East & North Africa; Latin America & the Caribbean and East Asia & Pacific) in all regressions. This reduces the possibility of obtaining spurious estimates. Our hypothesis is that: disease pathogens, via its effect on innovation; property rights; government effectiveness and globalization reduce the sustainable development. The OLS estimates in Table 1 support this hypothesis. The bivariate analysis in column (1) shows that the coefficient of historical prevalence of infectious disease is statistically significant at the 1% level and disease pathogens alone can explain about 60% of the total variation in sustainable development. The disease coefficients are estimated, even after controlling for ancestral characteristics of modern population and continent dummies in columns (2) and (3), respectively. In Colum (4) we add all control variables; the effect of disease pathogens remains robust. The results suggest that, an increase of standard deviation in the intensity of disease pathogens significantly reduces the sustainable development. We did not add political regime because we consider it as potential channel that will be tested in Section 5.

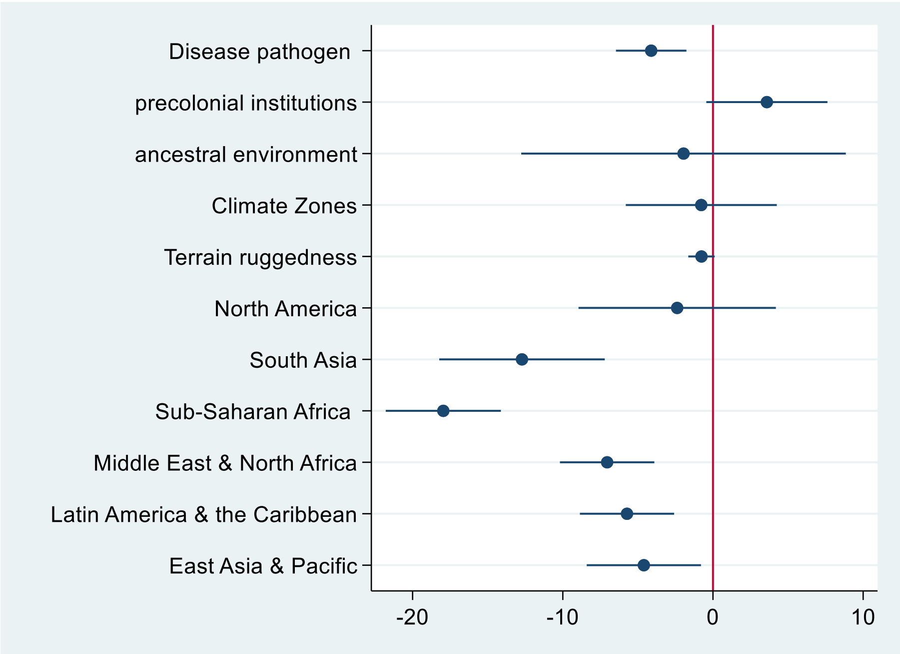
Table 1. Baseline results

	(1)	(2)	(3)	(4)
	Basic specification	Add Ancestral characteristics	Add Regional dummy	Full specification
Disease pathogen	**-11.983*** **	**-12.855*** **	**-4.395*** **	**-4.293*** **
	(0.832)	**(0.854)**	**(1.048)**	**(1.215)**
Precolonial institutions		8.867***		3.071
		(2.604)		(2.256)
Ancestral environment		-11.512***		-2.052
		(0.962)		(1.334)
Climate Zones		3.177		-1.452
		(2.318)		(2.210)
Terrain ruggedness		0.331		-0.709*
		(0.565)		(0.421)
North America			-3.067***	-2.538**
			(0.935)	(1.129)
South Asia			-11.037***	-12.160***
			(2.868)	(3.416)
Sub-Saharan Africa			-17.642***	-17.713***
			(1.692)	(1.904)
Middle East & North Africa			-6.626***	-6.876***
			(1.549)	(1.608)
Latin America & the Caribbean			-5.566***	-5.475***
			(1.439)	(1.585)
East Asia & Pacific			-3.201*	-3.654*
			(1.722)	(2.036)
Constant	70.200***	71.712***	75.814***	70.625***
	(0.542)	(4.220)	(0.764)	(2.980)
Observations	122	121	122	121
R^2	0.60	0.66	0.82	0.83
Fisher	207.39***	209.19***	88.38***	379.54***

Source: authors' construction. Notes: This table shows the correlation between disease pathogen including nine items(dengue, trypanosomes, schistosomes, leprosy, typhus, malaria, filariae, leishmanias, and tuberculosis) in the past and sustainable development using sustainable goals score index. Consistent with our prediction, the results suggest that a higher level of historical prevalence of infectious disease is associated with lower score in sustainable development. The results are robust to the inclusion of precolonial institutions; Terrain ruggedness; climates zones and ancestral environment controls and continental fixed effects. Robust standard errors are used and t-statistics are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Thus, variations in historical prevalence of infectious diseases can explain a reasonable fraction of the variation in sustainable development across countries. For example, countries with low prevalence of infectious disease like Canada (-1.31); Iceland (-1.19); Luxembourg (-1.11); Switzerland (-1.08); United Kingdom (-1.01) present good score performance in sustainable development (79.15; 78.17; 74.2093; 80.09 and 79.97) respectively. In contrast, countries with bad score performances in sustainable development (in percentage of GDP (Gross Domestic Product)) such as Chad (40) Cameroon (55); Madagascar (40) Malaysia (70) Philippines (64) present high level of infectious disease prevalence in the past (1.04; 1.17; 0.63; 0.5 and 0.5; respectively). The coefficient is negative and highly significant. This suggests that the observed differences in sustainable development between countries can be explained by cumulative variations in the historical prevalence of infectious diseases. In fact, coefficient plots with 95% confidence intervals from the baseline results in Figure 7 below show that the effect of disease pathogen is negative, and sub-Saharan African countries are less advanced in sustainable development strategies than the rest of the sub-region (North America; South Asia; Middle East & North Africa; Latin America & the Caribbean and East Asia & Pacific).

Figure 7. Coefficient plots with 95% confidence intervals



Source: authors' construction; ***Notes:*** Coefficient plots with 95% confidence intervals for baseline results. All coefficients are from equivalents to the benchmark column (4), Table 1. Sub-Saharan African countries are less advanced in sustainable development strategies than the rest of the sub-region (North America; South Asia; Middle East & North Africa; Latin America & the Caribbean and East Asia & Pacific).

4.2 Robustness Checks

4.2.1 Robustness to alternative measures of sustainable development and disease pathogens

We carry out several robustness checks of the results. The last column of Table 1, which is the complete specification, will be used as our baseline model for the purpose of this sensitivity analysis. That is, the estimations include all control variables used in the benchmark model but their estimates are not reported for the lack of space. We start by utilizing several alternative measures of sustainable development and disease pathogens. We also use cultural; history; geography controls and potential determinant of sustainable development. Table 2 below shows the results of our baseline specification with another two indexes of sustainable development, notably: one from Lange *et al*. (2019) and the second from Hickel (2020). The indexes have been discussed in the Data Section above. Our results remain robust. Disease pathogens are negatively associated with sustainable development.

Table 2. Other measures of sustainable development

	(1)	(2)	(3)
Dependent variable	Sustainable goals index Sachs *et al*. (2021)	Adjusted net saving Lange *et al*. (2019)	Ecological efficiency Hickel(2020)
Disease pathogen	**-4.293***** **(1.215)**	**-0.146***** **(0.042)**	**-11.073***** **(2.492)**
Baseline controls	Yes	Yes	Yes
Regional dummy	Yes	Yes	Yes
Constant	70.625*** (2.980)	-0.316*** (0.089)	0.226 (5.802)
Observations	121	113	121
R^2	0.83	0.44	0.51
Fisher	379.54***	19.27***	37.83***

Source: authors' construction. **Notes:** This table shows the correlation between disease pathogen including nine items(dengue, trypanosomes, schistosomes, leprosy, typhus, malaria, filariae, leishmanias, and tuberculosis) and another sustainable development index. Consistent with our prediction, our results remain robust. The results are robust to the inclusion of precolonial institutions; Terrain ruggedness; climates zones and ancestral environment controls and continental fixed effects. Robust standard errors are used and t-statistics are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 3 below shows the results of our baseline specification with another index of disease pathogens which include seven-item index (excluding both leprosy and tuberculosis) proposed by Gangestad and Buss (1993). Our results remain unchanged. So, the difference coming from both measures of sustainable development and disease pathogens does not affect our prediction. In this case, the difference coming from cross country disease prevalence can explain the difference in sustainable development observed between countries.

Table 3. Alternative measure of disease pathogens

	(1)	(2)	(3)	(4)
Dependent variable:	**Sustainable development index**			
Disease pathogen 7 Items	**-11.897***** **(0.852)**	**-12.503***** **(0.918)**	**-4.103***** **(0.997)**	**-3.880***** **(1.121)**
Baseline controls	No	Yes	No	Yes
Regional dummy	No	No	Yes	Yes
Constant	70.760*** (0.553)	72.510*** (4.504)	76.278*** (0.709)	70.757*** (2.992)
Observations	122	121	122	121
R^2	0.57	0.61	0.82	0.83
Fisher	194.91***	196.04***	94.56***	474.98***

Source: authors' construction; Notes: This table shows the correlation between disease pathogen including seven items (excluding leprosy and tuberculosis) in the past and sustainable development using sustainable goals score index. Consistent with our prediction, the results suggest that a higher level of historical prevalence of infectious disease is associated with lower score in sustainable development. The results are robust to the inclusion of precolonial institutions; Terrain ruggedness; climates zones and ancestral environment controls and continental fixed effects. Robust standard errors are used and t-statistics are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

4.2.2Robustness to supplementary control

In this sub-section, we run two supplementary controls. The first takes into account cultural, history and geography controls. The second includes the potential determinant of sustainable development. In Table 4, we control for several other exogenous forces. First, Bénabou *et al*. (2015) showed that religiosity variable is highly correlated with development, column(1) give the results of this controls. Second, Acemoglu *et al*. (2012) discussed the effect of colonization on current development. We include this specificity in column (3). In column (4), we take into account the finding of Alsan (2015) who highlighted that disease is highly correlated with landlocked, distance to equator; latitude and tropical zone. Next, Borcan *et al*. (2018) theoretically and empirically showed that development is closely linked to the state antiquity. Accordingly, column (5) allows for this effect. Finally, in column (6) all this controls are made. It is evident that the coefficients of historical prevalence of infectious disease remain significant in all cases.

Table 4. Cultural, history and other geography controls

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable:	Sustainable development index				
Disease pathogen	**-11.983*****	**-2.829****	**-4.210*****	**-4.647*****	**-4.588*****	**-3.043****
	(0.832)	**(1.257)**	**(1.254)**	**(1.289)**	**(1.386)**	**(1.330)**
Catholic trust		0.021				0.017
		(0.019)				(0.021)
Muslim trust		-0.039*				-0.028
		(0.020)				(0.027)
Protestant trust		0.040				0.042
		(0.025)				(0.030)
Ex-colony dummy			-0.438			-0.491
			(1.928)			(2.756)
Landlocked				-2.536*		-3.113*
				(1.345)		(1.741)
Distance to equator				-5.466		-8.761
				(9.340)		(11.320)
Latitude				-0.016		-0.003
				(0.036)		(0.050)
Tropical dummy				-5.207**		-6.761*
				(2.390)		(3.880)
State antiquity					3.000	3.298
					(2.283)	(2.979)
Base line controls	No	Yes	Yes	Yes	Yes	Yes
Regional dummy	No	Yes	Yes	Yes	Yes	yes
Constant	70.200***	72.761***	70.692***	71.053***	66.293***	70.263***
	(0.542)	(3.043)	(3.029)	(4.671)	(3.493)	(5.544)
Observations	122	113	120	99	105	84
R^2	0.60	0.85	0.83	0.87	0.84	0.89
Fisher	207.39***	277.05***	332.05***	215.96***	391.18***	153.70***

Source: authors' construction. **Notes:** This table shows the correlation between disease pathogen and sustainable development using sustainable goals score index taking into account cultural, history and geography controls. Consistent with our prediction, the results suggest that a higher level of historical prevalence of infectious disease is associated with lower score in sustainable development. The results are with this controls. Robust standard errors are used and t-statistics are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The above results demonstrate that the baseline findings are largely robust to using an alternative measure of our two principal variables, culture and geography controls; which at least partially accounts for omitted variables. This sub-section also accounts for other effects according to the potential determinant of sustainable development. More specifically, foreign direct investment (FDI) is associated with sustainable development. Aust *et al*. (2019) showed that the effect of FDI can be positive or negative. The variable presents a positive impact in areas which have access to basic infrastructure, clean water, sanitation, and renewable energy. In contrast, the effect of this variable is negative in goals related to climate action. Urbanization is an important variable for sustainable development (Filippini *et al.*, 2019; Khalil, 2011; Filippini *et al.*, 2019). According to Ganda, (2020), corruption was also found to worsen environmental sustainability in Africa. This control will be made in our model with government integrity. We also take into account the level of development recommended by the work of Jambor and Leitao (2017). Financial development and trade are equally added in the controls. Zahoor *et al.* (2022) recently show that financial development and urbanization encourage economic growth at the expense of environmental sustainability. The results reported in Table 5 below suggest that our main findings are not driven by these influences. In all cases, the coefficients of disease pathogens remain highly significant.

Table 5. Potential determinants of sustainable development

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Disease pathogen	**-11.983***** **(0.832)**	**-4.583***** **(1.194)**	**-2.689**** **(1.063)**	**-4.745***** **(1.247)**	**-3.866***** **(1.172)**	**-2.964**** **(1.346)**	**-4.016***** **(1.229)**	**-2.406**** **(1.181)**
Foreign Direct Investment		-0.225*** (0.051)						-0.259*** (0.082)
Financial development			12.215*** (2.188)					12.492*** (2.756)
Trade				-0.016 (0.011)				0.019 (0.013)
Government Integrity					0.055*** (0.020)			0.043** (0.021)
GDP per capita						0.000* (0.000)		-0.000 (0.000)
Urbanization							6.420** (3.191)	1.627 (3.193)
Baseline controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummy	No	Yes	Yes	Yes	Yes	Yes	Yes	yes
Constant	70.200*** (0.542)	71.694*** (2.979)	71.113*** (2.750)	71.591*** (3.143)	71.237*** (3.161)	72.125*** (2.968)	69.551*** (3.202)	71.209*** (3.332)
Observations	122	121	121	121	116	121	113	108
R^2	0.60	0.84	0.86	0.83	0.84	0.83	0.84	0.88
Fisher	207.39***	364.08***	280.99***	309.27***	181.29***	267.83***	337.36***	151.32***

Source: authors' construction; Notes: This table shows the correlation between disease pathogen and sustainable development using sustainable goals score index taking into account potential determinant of sustainable development. Consistent with our prediction, the results suggest that our main findings are not driven by these influences. In all cases, the coefficients of disease pathogens remain highly significant. Robust standard errors are used and t-statistics are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

5. Potential channels of influence

5.1 Potential channels linking disease prevalence to sustainable development

According to the parasite stress theory, a greater historical prevalence of infectious disease reduces the probability to develop innovation, globalization strategies and insurance to promote property rights and government effectiveness (Bennett & Nikolaev, 2021; Hill *et al.*, 2016; Nikolaev *et al.*, 2017; Thornhill *et al.*, 2009; Thornhill & Fincher, 2014; Varnum, &

Grossmann, 2017). Consequently, this negatively affects the incentive to invest in sustainable development. To test this hypothesis, we first regress disease pathogens on these four potential channels. The results in Table 6 below partially confirm this argument. Disease pathogens significantly reduce innovation, globalization, property rights and government effectiveness. The baseline controls have been taken into account to deal with omitted variable bias. Secondly, we control the incidence of this channels in the baseline regression by adding democracy and autocracy channels. Appendix C shows that, controlling for democracy and autocracy does not affect the robustness of our baseline results. So, we exclude these two variables as potential channels.

Table 6. Effect disease pathogens on potential channels

	(1)	(2)	(3)	(4)
	innovation	Government effectiveness	globalization	Property right
Disease pathogen	**-9.087***** **(2.126)**	**-0.874***** **(0.172)**	**-9.648***** **(3.011)**	**-0.629**** **(0.313)**
Baseline controls	**Yes**	**Yes**	**Yes**	**Yes**
Regional dummy	**Yes**	**Yes**	**Yes**	**Yes**
Constant	28.085*** (5.402)	-1.031** (0.429)	42.367*** (7.490)	8.910*** (0.276)
Observations	121	120	114	94
R^2	0.66	0.57	0.71	0.64
Fisher	165.88***	357.54***	185.69***	22.62***

Source: author's construction**. Notes:** This table shows the effect of disease pathogen on potential channels linking to sustainable development using sustainable goals score index.

Results are reported in Table 7. In Column (1), the effect of innovation is more significant than the influence of the historical prevalence of infectious diseases, as shown by its relatively larger t-statistic. The same observation can be made in Columns (3), (5) and (7) where we add the effects of property rights, government effectiveness and globalization, respectively. It is also relevant to note that the absolute value of the coefficient of disease pathogen and its significance fall drastically when these four variables (innovation, property rights, government effectiveness and globalization) are included. All combined, the evidence suggests that although we cannot rule out some direct impact from disease pathogens on sustainable development, a considerable amount of this influence occurs through these four variables. Building from the work of Zelekha (2016) and Bennett and Nikolaev (2021), these variables (innovation, property rights, government effectiveness and globalization) should be seen as the main transmission channels for the effect of the historical prevalence of infectious diseases on sustainable development. In this case, according to the authors, the historical variable (disease pathogen) is a good instrument to control for the effect of innovation, property rights, government effectiveness and globalization on sustainable development.

Table 7. Controlling by interaction of potential channels

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: sustainable development							
Disease pathogen	-0.947	-10.819***	-1.934	-14.101***	-0.669	-4.552***	-1.350	-8.443**
	(1.038)	(3.509)	(1.286)	(4.372)	(1.159)	(1.266)	(1.089)	(4.238)
Global innovation	0.350***							
	(0.045)							
Disease X innovation		0.176**						
		(0.083)						
Property right			1.931***					
			(0.354)					
Disease X property right				1.423***				
				(0.491)				
Government					3.908***			
					(0.857)			
Disease X government						1.182		
						(0.973)		
Globalization							0.255***	
							(0.033)	
Disease X globalization								0.073
								(0.061)
Constant	60.940***	66.702***	59.069***	71.453***	75.136***	69.493***	59.790***	68.908***
	(2.457)	(3.644)	(4.286)	(4.013)	(2.824)	(3.287)	(2.700)	(3.337)
Observations	120	120	93	93	119	119	113	113
R^2	0.89	0.84	0.86	0.84	0.88	0.83	0.88	0.83
Fisher	318.48***	275.81***	67.38***	68.94***	386.36***	224.95***	807.20***	199.93***

Source: authors' construction. **Notes:** This table shows the effect of disease pathogen on sustainable development using sustainable goals score index taking into account the interaction of potential channels liking to sustainable development. Taken together, the evidence suggests that although we cannot rule out some direct impact from disease pathogens on sustainable development, a considerable amount of this influence occurs through four variables. Robust standard errors are used and t-statistics are reported in the parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Government represents government effectiveness.

5.2 Mediation analysis

To confirm the discussed mediation channels, we test the effectiveness of mediation in Table 8 using the approaches of Zhao *et al.* (2010) and Baron and Kenny (1986). Results in Table 8 indicate that the null hypothesis of no mediation is rejected at the 1% level of significance for our three potential channels. The estimates also suggest that about 84% of the effect of disease pathogens on sustainable development is channelled through innovation, 63% through property rights, 85% through government effectiveness and 79% through globalization, suggesting that these variables are important channels of influence.

Table 8. Mediation analysis using structural equations modelling

Mediation variables	(1)	(2)	(3)	(4)
Dependent variable: sustainable development				
Mediator:	Global innovation index	Property right	Government effectiveness	Globalization
Step 1 (X -> M)	-0.735***	-0.689***	-0.698***	-0.772***
	(0.000)	(0.000)	(0.000)	(0.000)
Step 2 (M -> Y)	0.455***	0.331***	0.361***	0.436***
	(0.000)	(0.000)	(0.000)	(0.000)
Step 3 (X -> Y)	-0.063	-0.134	-0.044	-0.089
	(0.326)	(0.103)	(0.523)	(0.191)
Sobel test (of indirect effect)	-0.335***	-0.228***	-0.252***	-0.336***
	(0.000)	(0.000)	(0.000)	(0.000)
RIT	0.842	0.630	0.853	0.790
RID	5.314	0.327	5.785	3.762
Baseline controls	Yes	Yes	Yes	Yes
Conclusion ZLC	**full mediation**	**full mediation**	**full mediation**	**full mediation**
Conclusion BK	**mediation is complete**	**mediation is complete**	**mediation is complete**	**mediation is complete**
Percentage of mediation	**84 %**	**63%**	**85%**	**79 %**

Source: authors' construction; **Notes:** This table reports the partial results of structural equation modelling and distinguishes direct and indirect effects. P-value are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. RIT = (Indirect effect / Total effect). RID = (Indirect effect / Direct effect) ZLC: Zhao, Lynch and Chen (2010); BK: Baron and Kenny (1986).

The previous results show that our main channels through which historical prevalence of infectious disease can influence sustainable development are significant. We therefore test whether the reduced-form effect of disease pathogens operates through this four variables (innovation, property right, government effectiveness and globalization) using an instrumental variable method in two stages. The results are reported in Table 9. We treat our channels as endogenous. We use three instruments. The first one is historical prevalence of infectious disease. We then add life expectancy and expected years in school because according to Diamond (1997), these two variables are determined by ecological condition in the past and they equally affect sustainable development. If this occurs, then property right; government effectiveness; innovation and globalization, are likely to significantly affect sustainable development.

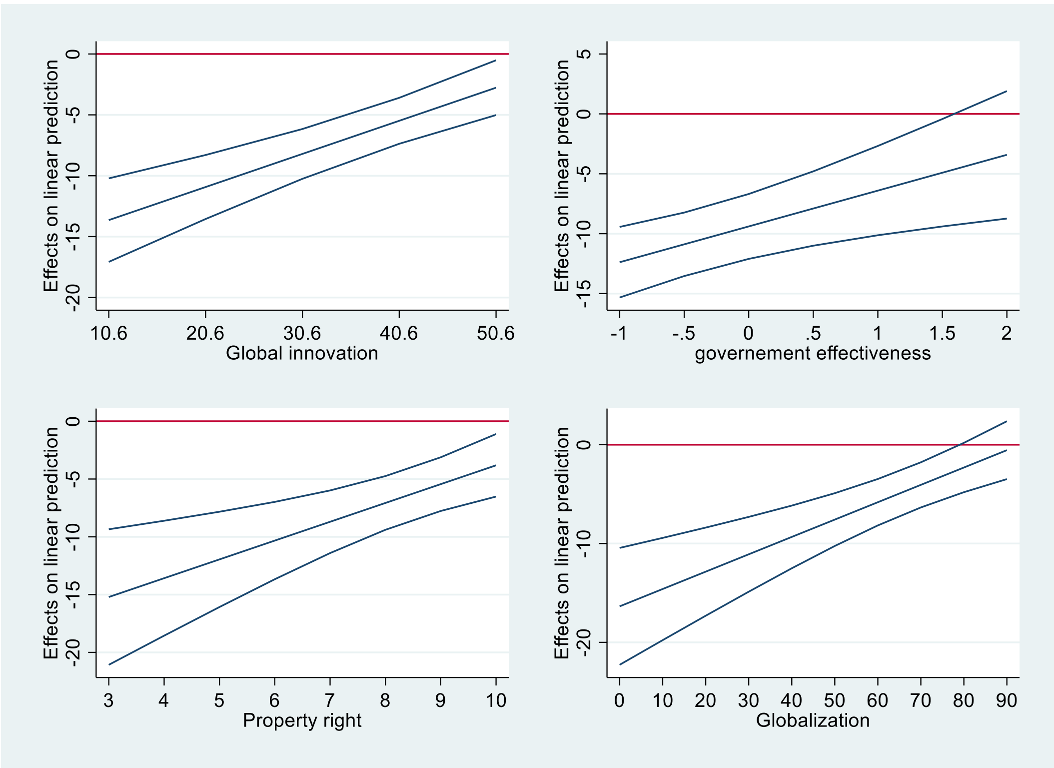
Table 9. Dealing with endogeneity

Panel A: 2nd-stage regressions				
	(1)	(2)	(3)	(4)
Dependent variable: sustainable development				
Global innovation	1.226***			
	(0.327)			
Government effectiveness		12.910***		
		(3.307)		
Globalization			1.206***	
			(0.339)	
Property right				7.794***
				(2.531)
Baseline controls	Yes	Yes	Yes	Yes
Regional dummy	Yes	Yes	Yes	Yes
Potentials determinants	Yes	Yes	Yes	Yes
Constant	35.057***	82.505***	20.138	25.848*
	(10.969)	(4.569)	(15.248)	(14.579)
Observations	106	106	101	83
R^2	0.76	0.75	0.68	0.64
Hansen over-identification test (p-value)	0.41	0.37	0.24	0.21
Anderson-Rubin endogeneity test (p-value)	0.00	0.00	0.00	0.00
LM test for under identification (p-value)	0.01	0.00	0.03	0.04
Panel B: 1st-stage regressions				
Dependent variable	Global innovation	Government effectiveness	Globalization	Property right
Disease pathogen	-9.087***	-0.874***	-9.648***	-0.629**
	(2.126)	(0.172)	(3.011)	(0.313)
Baseline controls	Yes	Yes	Yes	Yes
Regional dummy	Yes	Yes	Yes	Yes
Constant	28.085***	-1.031**	42.367***	8.910***
	(5.402)	(0.429)	(7.490)	(0.276)
Observations	121	120	114	94
R^2	0.66	0.57	0.71	0.64
Fisher	165.88	357.54	185.69	22.62

Notes: This table reports 2SLS estimates of the effects of disease pathogen on present-day sustainable development. **Instruments**: historical prevalence of infectious disease, Life expectancy, Expect year schooling. Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

We run the estimations with robust option using command "ivreg2" in Stata. The p-value of Anderson-Rubin test of endogenous regressor is significant at the 1% level. We conduct the weak instrument-robust inference using the approach of Anderson and Rubin (1949). According to Ang et al. (2018), this method, which is robust to the presence of weak instruments, tests the significance of the endogenous regressor in the structural equation. The test rejects the null hypothesis that the coefficient of the endogenous regressor is equal to zero at the 5% level of significance, thus providing evidence that our endogenous regressor is relevant even in the presence of a weak instrument. The results indicate that the exogenous component of property rights, government effectiveness, innovation and globalization exert a strong positive effect on sustainable development, and this effect is statistically significant at the 1% level. The p-value under identification is significant at the 1% level, suggesting that historical prevalence of infectious disease is a strong instrument. Through the results in Table 9, we also find the marginal effects of disease pathogens on sustainable development, conditional on innovation, government effectiveness, property right and globalization in Figure 6. This Figure confirms that the promotion of innovation, government effectiveness, globalization and the guarantee of property rights, moderate the effects of historical prevalence of infectious disease on sustainable development.

Figure 8. Conditional marginal effects of disease pathogens on sustainable development



Source: authors' construction; ***Notes:*** Note: The upper and lower dashed blue lines represent the 95% confidence intervals. This figure confirms that the promotion of innovation, government effectiveness, globalization and the guarantee of property right moderate the effects of historical prevalence of infectious disease on sustainable development.

6. Concluding implication and future research directions

The study on the driving forces behind persistent high levels of sustainable development is an important inquiry in mainstream economics. Previous studies have revealed the persistent effects of historical prevalence of infectious diseases, across culture, political regime, and institutions. The novelty of this article lies in the fact that we have taken a historical approach that illuminates the deep historical roots of differences in sustainable development across countries.

This article equally examines the effects of the age of environmental quality on institutions, innovation, and environmental literacy across countries. Thornhill *et al*. (2009), for example, show that variation in values for autocracy and democracy is determined by historical diseases. This article thus provides additional support for the importance of innovation, property rights, government effectiveness and globalization between the historical prevalence of infectious diseases and sustainable development (Bennett & Nikolaev, 2021; Hill *et al*., 2016; Nikolaev *et al*., 2017; Thornhill *et al*., 2009; Thornhill & Fincher, 2014; Varnum, & Grossmann, 2017). Using data of 122 countries, we find that historical prevalence of infectious disease persists and significantly reduces sustainable development through property rights, innovation, globalization and government effectiveness. This result is robust to: the change in method; alternative measures of sustainable development and disease pathogens; the characteristics of the economies and to the potential determinants of sustainable development.

The main implication of this study is that government effectiveness, innovation, property rights and globalization should be promoted as a means of fighting disease pathogens and by extension, promoting sustainable development. It follows that countries that substantially invest in favour of an economic development culture that is supportive of government effectiveness, guaranty of property right, globalization and innovation are also likely to benefit from a comparatively less disease burden and sustainable development.

Future studies can focus on investigating how the historical prevalence of diseases is affecting other contemporary economic development outcomes. Moreover, it is also worthwhile to assess how the contemporary prevalence of a global pandemic such as the COVID-19 is affected by both non-contemporary macroeconomic and health indicators.

References

Acemoglu, D., Johnson, S., & Robinson, J. A. (2001). The Colonial Origins of Comparative Development : An Empirical Investigation. *American Economic Review*, *91*(5), 1369–1401. http://www.jstor.org/stable/2677930

Acemoglu, D., Johnson, S., & Robinson, J. A. (2012). The colonial origins of comparative development: An empirical investigation: Reply. *American Economic Review*, *102*(6), 3077–3110. https://doi.org/10.1257/aer.102.6.3077

Alesina, A., Giuliano, P., & Nunn, N. (2013). On the origins of Gender roles: women and the plough. *The Quarterly Journal of Economics*, *128*(May), 469–530. https://doi.org/10.1093/qje/qjt005.Advance

Alsan, M. (2015). The Effect of the TseTse Fly on African Development. *American Economic Review*, *105*(1), 382–410.

Amavilah, V., Asongu, S. A., & Andrés, A., R., (2017). "Effects of globalization on peace and stability: Implications for governance and the knowledge economy of African countries", *Technological Forecasting and Social Change*, 122: 91-103.

Anderson, T. W., & Rubin, H. (1949). Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations. *The Annals of Mathematical Statistics*, *20*(1), 46–63. https://doi.org/10.1214/aoms/1177730090

Ang, J. B., & Fredriksson, P. G. (2018). State History, Legal Adaptability and Financial Development. *Journal of Banking and Finance*, *Accepted M*. https://doi.org/10.1016/j.jbankfin.2018.02.009

Ang, J. B., Fredriksson, P. G., Luqman, A., & Tay, E. H. (2018). Sunlight , Disease , and Institutions. *Kyklos*, *71*(3), 374–401. https://doi.org/10.1111/kykl.12174

Asongu, S. A., & Odhiambo, N. M. (2019a). Foreign direct investment, information technology and economic growth dynamics in sub- Saharan Africa. *Telecommunications Policy*, 44(1):101838.

Asongu, S. A., & Odhiambo, N. M. (2019b). How enhancing information and communication technology has affected inequality in Africa for sustainable development: An empirical investigation. *Sustainable Development*, (December 2018), 1–10.

Asongu, S. A., & Odhiambo, N. M. (2019c). Inequality and gender inclusion: Minimum ICT policy thresholds for promoting female employment in sub-Saharan Africa. *Telecommunications Policy*, 44(4), 101900.

Asongu, S. A., & Odhiambo, N. M. (2020). How enhancing gender inclusion affects inequality: Thresholds of complementary policies for sustainable development, *Sustainable Development*, 28(1), 132–142.

Aust, V., Morais, A. I., & Pinto, I. (2019). How does foreign direct investment contribute to Sustainable Development Goals? Evidence from African countries. *Journal of Cleaner Production*, *accepted m*, 118823. https://doi.org/10.1016/j.jclepro.2019.118823

Bénabou, B. R., Ticchi, D., & Vindigni, A. (2015). MORAL VALUES AND ECONOMIC BEHAVIOR: Religion and Innovation. *American Economic Review*, *105*(5), 346–351.

Bennett, D. L. (2018). Infrastructure investments and entrepreneurial dynamism in the. *Journal of Business Venturing*, *January*, 1–28. https://doi.org/10.1016/j.jbusvent.2018.10.005

Bennett, D. L. (2019). Infrastructure investments and entrepreneurial dynamism in the. *Journal of Business Venturing*, *34*(5), 105907. https://doi.org/10.1016/j.jbusvent.2018.10.005

Bennett, D. L., & Nikolaev, B. (2021). Historical Disease Prevalence, Cultural Values, and Global Innovation. *Entrepreneurship: Theory and Practice*, *45*(1), 145–174. https://doi.org/10.1177/1042258720914506

Borcan, O., Olsson, O., & Putterman, L. (2018). State history and economic development : evidence from six millennia. *Journal of Economic Growth*, *23*(1), 1–40. https://doi.org/10.1007/s10887-017-9152-0

Comin, D., Easterly, W., & Gong, E. (2010). Was the Wealth of Nations Determined in 1000 bc? *American Economic Journal: Macroeconomics*, *2*(July), 65–97.

Diamond, J. (1997). Guns, Germs, And Steel. The Fates Of Human Societies. *Norton, New York*.

Filippini, R., Mazzocchi, C., & Corsi, S. (2019). The contribution of Urban Food Policies toward food security in developing and developed countries: A network analysis approach. *Sustainable Cities and Society*, *47*(March), 101506. https://doi.org/10.1016/j.scs.2019.101506

Fincher, C. L., Thornhill, R., Murray, D. R., Schaller, M., & Fincher, L. (2013). *predicts human Pathogen prevalence variability in individualism / collectivism*. *275*(1640), 1279–1285. https://doi.org/10.1098/rspb.2008.0094

Ganda, F. (2020). The influence of corruption on environmental sustainability in the developing economies of Southern Africa. *Heliyon*, *6*(7), e04387. https://doi.org/10.1016/j.heliyon.2020.e04387

Gangestad, S. W., & Buss, D. M. (1993). Pathogen Prevalence and Human Mate Preferences. *Ethology and Sociobiology*, *96*, 89–96.

Gelfand, M. J., Bhawuk, D. P. S., Nishii, L. H. & Bechtold, D. J. (2004). *Individualism and collectivism. In Culture, Leadership, and Organizations: The GLOBE Study of 62 Societies,*. (eds. R. J. House).

Giuliano, P., & Nunn, N. (2018). Ancestral Characteristics of Modern Populations ANCESTRAL CHARACTERISTICS OF. *Economic History of Developing Regions*, *33*(1), 1–17. https://doi.org/10.1080/20780389.2018.1435267

Hickel, J. (2020). The sustainable development index : Measuring the ecological efficiency of human development in the anthropocene. *Ecological Economics*, *167*(March 2019), 106331. https://doi.org/10.1016/j.ecolecon.2019.05.011

Hill, S. E., Boehm, G. W., & Prokosch, M. L. (2016). Vulnerability to Disease as a Predictor of Faster Life History Strategies. *Adaptive Human Behavior and Physiology*, *2*, 116–133. https://doi.org/10.1007/s40750-015-0040-6

Jambor, A., & Leitao, N. C. (2017). Economic growth and sustainable development: Evidence from central and eastern Europe. *International Journal of Energy Economics and Policy*, *7*(5), 171–177.

Keisu, M. R. B.-I. (2013). Constructions of innovation and gender (equality) in Swedish universities. International Journal of Gender and Entrepreneurship, 5(3), 342–356. https://doi.org/10.1108/IJGE-09-2012-0047

Khalil, F. (2011). Urban sprawl vs urban renewal: What role for town and country planning instruments in ensuring sustainable cities? Case of Algeri. *Procedia Engineering*, *21*, 760–766. https://doi.org/10.1016/j.proeng.2011.11.2075

Koirala, B. S. (2019). Determinants of sustainable development : Evidence from 12 Asian countries. *Sustainable Development*, *February*, 1–7. https://doi.org/10.1002/sd.1963

Lange, Glenn-Marie; Wodon, Quentin; Carey, K. (2019). Estimating the World Bank ' s Adjusted Net Saving : Methods and Data. *Washington, DC: World Bank*. https://doi.org/https://datacatalog.worldbank.org/dataset/Adjusted-Net-Savings

Omang, O. M., Asongu, S. A., & Tchamyou, V. S. (2022). Historical prevalence of infectious diseases and gender equality in 122 countries. ASPROWORDA Working Paper No. 005, Yaoundé.

Murray, D. R., & Schaller, M. (2010). Historical prevalence of infectious diseases within 230 geopolitical regions: A tool for investigating origins of culture. *Journal of Cross-Cultural Psychology*, *41*(1), 99–108. https://doi.org/10.1177/0022022109349510

Murray, D. R., Schaller, M., & Suedfeld, P. (2013). Pathogens and Politics: Further Evidence That Parasite Prevalence Predicts Authoritarianism. PLoS ONE, 8(5). https://doi.org/10.1371/journal.pone.0062275

Murray, D. R., Trudeau, R., & Schaller, M. (2011). On the origins of cultural differences in conformity: Four tests of the pathogen prevalence hypothesis. Personality and Social Psychology Bulletin, 37(3), 318–329. https://doi.org/10.1177/0146167210394451

Nikolaev, Boris and Salahodjaev, R. (2017). Historical Prevalence of Infectious Diseases , Cultural Values , and the Origins of Economic Institutions Historical Prevalence of Infectious Diseases , Cultural Values , and the Origins of Economic Institutions. *Munich Personal RePEc Archive*, *78435*.

Nikolaev, B., Boudreaux, C., & Salahodjaev, R. (2017). Journal of Economic Behavior & Organization Are individualistic societies less equal ? Evidence from the parasite stress theory of values. *Journal of Economic Behavior and Organization*, *138*, 30–49. https://doi.org/10.1016/j.jebo.2017.04.001

Saâd, M. B.,& Assoumou-Ella, G. (2019). Complexity and Gender Inequality in Education : An Empirical Study. *Economics Bulletin*, *39*(1), 321–334.

Sachs J, Kroll C, Lafortune G, Fuller G, W. F. (2021). *The Decade of Action for the Sustainable Development Goals: Sustainable Development Report 2021*. (C. U. Press (ed.); ISBN 978-1). Cambridge University Press. https://doi.org/10.1017/9781009106559

Sagiv, L., & Schwartz, S. H. (1995). Value Priorities and Readiness for Out-Group Social Contact. *Journal of Personality and Social Psychology*, *69*(3), 437–448. https://doi.org/10.1037/0022-3514.69.3.437

Schaller, M., & Murray, D. R. (2008). Pathogens , Personality , and Culture : Disease Prevalence Predicts Worldwide Variability in Sociosexuality , Extraversion , and Openness to Experience. 95(1), 212–221. https://doi.org/10.1037/0022-3514.95.1.212

Svirydzenka, K. (2016). Introducing a New Broad-based Index of Financial Development. *IMF Working Papers*, *16*(05), 1. https://doi.org/10.5089/9781513583709.001

Thornhill, R, & Fincher, C. L. (2014). Stress Theory of Values and Sociality. In *Springer*. Springer. https://link.springer.com/content/pdf/10.1007/978-3-319-08040-6.pdf

Thornhill, Randy, & Fincher, C. L. (2011). Parasite stress promotes homicide and child maltreatment. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1583), 3466–3477. https://doi.org/10.1098/rstb.2011.0052

Thornhill, Randy, & Fincher, C. L. (2014). The parasite-stress theory of sociality, the behavioral immune system, and human social and cognitive uniqueness. *Evolutionary Behavioral Sciences*, *8*(4), 257–264. https://doi.org/10.1037/ebs0000020

Thornhill, Randy, Fincher, C. L., & Aran, D. (2009). Parasites, democratization, and the liberalization of values across contemporary countries. *Biological Reviews*, *84*(1), 113–131. https://doi.org/10.1111/j.1469-185X.2008.00062.x

Varnum, Michael e. W. Grossmann, I. (2017). Pathogen prevalence is associated with cultural changes in gender equality. *Nature Human Behaviour*, *1*(1), 14–17. https://doi.org/10.1038/s41562-016-0003

WIPO. (2021). Global Innovation Index 2021: Tracking Innovation through the COVID-19 Crisis. Geneva: World Intellectual Property Organization. (B. L. Soumitra Dutta & L. R. L. and S. Wunsch-Vincent (eds.)).

Wrigley, J. (1992). Education and Gender Equality (W. 2ET UK The Falmer Press, 4 John Street, London (ed.); First publ).

Zahoor, Z., Khan, I., & Hou, F. (2022). Clean energy investment and financial development as determinants of environment and sustainable economic growth: evidence from China. *Environmental Science and Pollution Research*, *29*(11), 16006–16016. https://doi.org/10.1007/s11356-021-16832-9

Appendix A

Descriptive statistics

Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	source
Sustainable development Index	122	68.521	10.143	40.904	85.901	Sachs etal.(2021)
Disease pathogen	122	.135	.659	-1.31	1.17	Murray and Schaller(2010)
precolonial institutions	121	.106	.265	0	.999	Giuliano and Nunn(2018)
ancestral environment	121	.007	.076	0	.833	Giuliano andNunn(2018)
Climate Zones	120	.061	.19	0	1	Giuliano andNunn(2018)
Terrain ruggedness	120	-7.235	.989	-10.152	-5.592	Giuliano andNunn(2018)
catholic trust	113	32.089	36.049	0	96.9	Acemoglu et al.(2001)
muslim trust	113	23.238	35.355	0	99.4	Acemoglu et al.(2001)
protestant trust	119	12.344	21.783	0	97.8	Acemoglu et al.(2001)
Ex-colony dummy	119	.546	.5	0	1	Acemoglu et al.(2001)
Landlocked	105	.171	.379	0	1	Comin et al.(2010)
Distance to equator	99	.294	.195	.003	.669	Comin et al.(2010)
Latitude	99	19.119	25.46	-36.676	60.212	Comin et al.(2010)
Tropical dummy	105	.476	.502	0	1	Comin et al.(2010)
State antiquity ang	104	.488	.234	.028	.964	Ang and Fredriksson(2018)
Foreign Direct Investment	121	3.496	4.741	-4.054	41.193	World bank (2021)
Financial development	121	.287	.206	.007	.816	Svirydzenka, (2016)
trade	121	73.61	42.355	9.706	330.495	World bank (2021)
Government intergrity	116	42.553	21.007	13.554	93.765	Freedom house (2020)
gdp per capita	121	7120.16	8811.484	153.095	38834.801	V-DEM(2021)
Urbanization	112	.329	.186	.051	1.018	V-DEM(2021)
Global innovation	122	35.597	12.841	10.6	66.6	V-DEM(2021)
government effectiveness	120	.189	.929	-1.41	2.148	WIPO(2021)
Globalization	114	58.858	16.99	27.909	91.245	Kof index of globalization(2017)
Property right	93	7.362	1.672	3.636	10	Acemoglu et al.(2001)
Institutionalized autocracy	115	-2.299	12.037	-66	9.261	V-DEM(2021)
Institutionalized democracy	115	.49	13.249	-66	10	V-DEM(2021)
North America	122	.016	.128	0	1	World Bank classification (2021)
South Asia	122	.033	.179	0	1	World Bank classification (2021)
Sub-Saharan Africa	122	.246	.432	0	1	World Bank classification (2021)
Middle East & North Africa	122	.115	.32	0	1	World Bank classification (2021)
Latin America & the Caribbean	122	.139	.348	0	1	World Bank classification (2021)
East Asia & Pacific	122	.115	.32	0	1	World Bank classification (2021)

Appendix B

	(1)											
	SDG	disease	v33_grp	v95_grp	kg_code	lnavgrug	na_dumy	sa_dumy	sub_sa_dumy	mena_ddumy	lac_dumy	eap_dumy
SDG	1											
disease	-0.754***	1										
	(0.000)											
v33_grp	0.0733	0.110	1									
	(0.424)	(0.231)										
v95_grp	-0.117	0.0103	-0.0365	1								
	(0.202)	(0.911)	(0.691)									
kg_code	-0.0483	0.122	-0.00811	-0.0297	1							
	(0.600)	(0.184)	(0.930)	(0.747)								
lnavgrug	-0.0849	0.190*	0.166	-0.0665	0.0452	1						
	(0.356)	(0.038)	(0.071)	(0.471)	(0.624)							
na_dumy	0.116	-0.220*	-0.0518	-0.0117	-0.0422	0.0662	1					
	(0.204)	(0.015)	(0.572)	(0.899)	(0.647)	(0.473)						
sa_dumy	-0.113	0.0881	0.273**	-0.0169	0.141	0.0261	-0.0238	1				
	(0.217)	(0.334)	(0.002)	(0.854)	(0.124)	(0.777)	(0.795)					
sub_sa_dumy	-0.786***	0.554***	-0.229*	0.159	-0.127	-0.111	-0.0737	-0.105	1			
	(0.000)	(0.000)	(0.012)	(0.082)	(0.166)	(0.226)	(0.420)	(0.249)				
mena_ddumy	-0.00654	0.0756	0.0748	-0.0330	-0.118	0.105	-0.0465	-0.0663	-0.206*	1		
	(0.943)	(0.408)	(0.415)	(0.719)	(0.200)	(0.255)	(0.611)	(0.468)	(0.023)			
lac_dumy	0.0235	0.121	-0.0186	-0.0369	0.174	0.0794	-0.0519	-0.0741	-0.230*	-0.145	1	
	(0.797)	(0.184)	(0.839)	(0.688)	(0.057)	(0.389)	(0.570)	(0.417)	(0.011)	(0.111)		
eap_dumy	0.0668	0.0925	0.342***	-0.0330	0.366***	0.0943	-0.0465	-0.0663	-0.206*	-0.130	-0.145	1
	(0.465)	(0.311)	(0.000)	(0.719)	(0.000)	(0.305)	(0.611)	(0.468)	(0.023)	(0.155)	(0.111)	
N	123											

SDG = sustainable development ; v33_grp = precolonial institutions; v95_grp = ancestral environment; kg_code = Climate Zones; lnavgrug =Terrain ruggedness; na_dumy = North America; sa_dumy= South Asia; sub_sa_dumy= Sub-Saharan Africa; mena_ddumy= Middle East & North Africa; lac_dumy = Latin America & the Caribbean; eap_dumy= East Asia & Pacific

Appendix c: controlling the interaction of political regime

Table 7. transmission channels

	(1)	(2)	(3)	(4)
Disease pathogen	-4.513***	-4.557***	-4.479***	-4.402***
	(1.279)	(1.309)	(1.259)	(1.294)
democracy	0.002			
	(0.036)			
Disease X democracy		0.070		
		(0.090)		
autocracy			-0.010	
			(0.040)	
Disease X autocracy				0.084
				(0.102)
Baseline controls	Yes	Yes	Yes	Yes
Regional dummy	Yes	Yes	Yes	Yes
Constant	70.597***	70.359***	70.390***	70.282***
	(3.151)	(3.050)	(3.160)	(3.060)
Observations	115	115	115	115
R^2	0.83	0.83	0.83	0.83
Fisher	365.46	243.75	371.47	725.01

p < 0.10, ** p < 0.05, *** p < 0.01

LISTE OF COUNTRIES

Albania	Chile	Hungary	Mali	Sierra leone	Vietnam
Algeria	China	Iceland	Mauritania	Singapore	Zambia
Angola	Colombia	India	Mayanmar	Slovakia	
Argentina	Costa Rica	Indonesia	Mexico	Slovenia	
Armenia	Cote d'ivoire	Iran	Moldova	South Africa	
Australia	Croatia	Ireland	Morocco	Spain	
Austria	Cyprus	Israel	Mozambique	Sri Lanka	
Azerbaijan	CzechRep.	Italy	Namibia	Suriname	
Bahrain	Denmark	Jamaica	Netherlands	Swaziland	
Bangladesh	Ecuador	Japan	Nigeria	Sweden	
Belgium	Egypt	Jordan	Norway	Switzerland	
Benin	El Salvador	Kenya	Oman	Syria	
Bolivia	Estonia	Korea south	Pakistan	Tanzania	
Bosnia	Ethiopia	Kuwait	Panama	Thailand	
Botswana	Finland	Laos	Peru	Trinidad and tobago	
Brazil	France	Latvia	Philippines	Tunisia	
Brunei	Gabon	Lebanon	Poland	Turkey	
Bulgaria	Gambia	Liberia	Portugal	Uganda	
Burkina faso	Georgia	Lithuania	Romania	Ukraine	
Burundi	Germany	Luxembourg	Russia	United Arabe emirate	
Cambodia	Ghana	Macedonia	Rwanda	United Kindom	

Cameroon	Greece	Madagascar	Saudi arabia	Uruguay	
Canada	Guatemala	Malawi	Senegal	USA	
Chad	Guinea	Malaysia	Serbia Montengro	Venezuela	