Agricultural Land Consumption in Developed Countries

Guido Sali
Department of Agricultural and Environmental Sciences, University of Milan
guido.sali@unimi.it

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Abstract

The amount of agricultural land available in developed countries is decreasing by a degree which may profoundly affect in the long term the food security. This paper reports a quantitative investigation of the factors that contribute to this decrease, by analysing 30 countries during the period 1995-2009. The panel data analysis suggests that a variety of phenomena are associated with the decline in agricultural land: a high level of gross domestic product, an increase in the size of urban areas and transport networks, and an increase in agricultural productivity. This last factor is linked to the abandonment of the least productive plots of land and to its conversion to forest. In contrast, an higher quality of institutions is associated with a reduction in the rate of cropland loss. This suggests that a qualitative growth in institutional quality determines a greater attention to agricultural land as a resource for the supply of food products and environmental services.

Keywords: Agricultural land loss, panel data analysis, developed countries, land use change, urbanisation

1. Introduction

The availability of cropland is an issue of great importance, because of its implications both on food security in many countries and on the likelihood of meeting future dietary needs for the whole world (FAO, 2011). Despite the need to maintain a sufficient amount of cropland, this seems to be negatively related to GDP. This is portrayed in the scatter graph in figure 1. Here, the yearly average rate of variation in agricultural land between 1995 and 2009 is compared to pro-capita GDP in 1995. It appears evident that agricultural land has increased in countries with a low GDP, while it has lowered in rich countries.

This phenomenon equates to 36.5 million hectares of cropland generated in low and lower-middle income countries, and to a loss of 29.4 million hectares in high and upper-middle income countries (Table 1). This corresponds to a transfer of agricultural land from countries with high income levels to those with low ones.

The aim of the present paper is to explore this negative correlation between GDP and agricultural land change, to discover the contributing factors behind this decline in developed countries. The focus on developed economies is due to the dissimilar dynamics of countries with different economic development that go beyond the data summarised in Fig.1. Consequently, it is not easy to develop a theoretical model which describes the evolution of agricultural land in countries with differing levels of development without imposing restrictive assumptions on growth and land use change.

As a matter of fact, the underlying causes of land use change seem very diverse in developing and developed countries. A great deal of literature has been generated on the study of land use change in developing countries. Here the formation of agricultural land is due mainly to deforestation (Lambin et al., 2001), so strongly that the former is often used as a proxy for the latter (Barbier, 2004; Scrieciu, 2006).

Lambin et al. (2001) define several important factors which lead to the processes of land use and land cover change in developing countries. Poverty and population growth play an important role: such socio-economic factors have been in particular analysed through the Environmental Kuznets Curve (EKC). According to an EKC, economic development is characterised by an initial environmental degradation, such as deforestation. The process of agricultural land formation (and consequently deforestation) is particularly intense in low and middle-income tropical countries in the presence of weak infrastructures, corruption and marked dependence on natural resources (Barbier et al., 2005). For instance, the need for structural adjustments after a debt crisis leads countries with weak infrastructures to exploit natural resources in a non-sustainable manner (Capistrano, 1994) in trying to keep the debt under control. These conditions favour the formation of large agricultural companies which make an intensive use both of resources and labour, also facilitated by the depreciation of local currencies which increases the profitability of agricultural export (Capistrano and Kiker, 1995). Similarly, the rate of deforestation is strongly linked to the global price of forestry product (Cropper and Griffiths, 1994), linking once again this problem to international trade. The presence of a solid common property rights structure has been shown to be critical (Coleman, 2011) as it stimulate an appropriate use of forest resources. Finally, a reduction in inequality leads to a better management of common resources (Andersson and Agrawal, 2001).

In developed countries the dynamics and the evolution of agricultural land is subject to driving forces of different nature, among which economic wealth. In fact, an high income level signals three concomitant phenomena.

The first is the decline of the agricultural sector within the process of economic development and the consequent migration of workforce and capital, included land, to other sectors (i.e. the Rostovian take-off model). Therefore, the demand for agricultural land appears to decline, given the lower structural productivity of the factors in this sector compared to that in the manufacturing industry. On the other hand, land for industrial, services and infrastructural use increases.
The second phenomenon is the increase both in welfare and environmental demand, which leads to a higher level of protection of natural resources. This also regards forest resources, which compete with agriculture for the use of land.

The last phenomenon is connected to the difficulty that many areas face in generating an adequate productivity and income according to the level of average welfare in the country in question. This last point is the main focus of agricultural policies in those developed countries that attempt to keep high agricultural incomes through the remuneration of social and environmental services offered to the public and through helps in redirecting the activity towards other sectors (tourism, commerce, artisanship etc.).

From these brief observations clearly emerges the fact that the specifications most appropriate to describe the evolution of agricultural land in developed countries are individual and not applicable to all countries. The paper will continue as follows. Section 2 will present the driving forces causing agricultural land use change in developed countries. Section 3 will introduce the econometric model and the explanatory variables. Data and results will be discussed in section 4, while section 5 will report the conclusions.

2. The causes of the loss of agricultural land

The causes underlying the loss of agricultural land (understood as arable and permanent crops) can be narrowed down to three: the conversion of agricultural land to non-agricultural uses, which we will refer to the simplifying term "urbanisation"; abandonment caused by a low productivity; conversion for other agro-forest uses.

Urbanisation is an important feature of the transformation of agricultural land: despite an estimated built-up and sealed surface of around only 2% of the earth's surface in the 90's (Grubler, 1994), urbanisation is closely linked to the economic growth. This relationship seems to be particularly evident in the case of fast-growing economies, such as China, where in the last years an increase in GDP by 10% led to an increase in urban land by 3% (Deng et al., 2010), to the detriment of arable land (Tin et al., 2005). This phenomenon is prevalent in developed countries, where urban expansion can take on various forms, such as the "sprawl". This is present especially in the United States, where it's characterised by low-density ex-urban areas (Glaser and Kahn, 2003), and in so-called peri-urban areas of many European countries.

Sprawl gradually breaks up the rural system through the establishment of settlements initially along communication routes. Thanks to the spread of the road network, it builds a territory which is no longer rural although not yet urban, where agricultural activity tends to decrease, leaving opportunities for industrial, commercial, infrastructural and residential settlements, together with green areas for recreational and landscaping uses (Lambin et al., 2001). Even if they are not completely urbanised areas, green areas (parks and gardens) can still be considered as areas subject to urban transformation, because they are generally created to respond to demand for green space generated by the urban population. As a result, they are closely connected to urban systems, such as the rural-fringes present around many European cities.

A clear indication of the urbanization process is also the increase in urban population, that has already overtaken the rural population in the world, and is going to grow further in coming decades, with an expected total of 4.8 billion by 2030 (United Nations Population Fund, 2007). The tendency to redirect agricultural land to urban expansion is considered to be a problem both in socio-economical and environmental terms (Nuissl et al., 2009). In fact, many countries have implemented policy instruments to reduce the soil consumption and to rationalise land use (Liu and Linch, 2011; Tan et al., 2009; Ding 2003).

The **abandonment of agricultural activity** also contributes to the reduction of agricultural land. Generally, this phenomenon is contingent on an insufficient productivity of viable cultures, which in turn can be the consequence of two different phenomena: natural variation and variation in economic conditions (Lambin and Meyfroidt, 2010). The first relates to the variation in the physical conditions of the soil: erosion, salt content, fire risk, climate change, and landscape fragmentation (Salvati and Zitti, 2009). This includes phenomena with a natural or man-made origin but which have in common a reduction in the productive capacity of the soil. There are few international statistics for these phenomena, investigated in many regional-scale studies. The variation in economic conditions relates to a change in competitiveness. The globalisation of the markets and the consequent pressure on prices has reduced farming profitability, especially those in structurally weak areas, such as hills, mountains and outlying areas (Brouwer et al., 2008). Despite the intense effort of the governments in developed countries in supporting agriculture, this sector remains vulnerable to competition from countries with low costs of labour, with a real risk of abandonment of crops. Indeed, in the European Union the Fischler Reform has introduced the obligation of maintaining good agronomic and environmental conditions of the land even in the absence of crops, acknowledging that the decision of the farmer to opt out from cultivating is a far from remote option.

Finally, there is the possibility of the **conversion of arable land** or of permanent crops **to other uses** such as pasture or woodland. In Table 2 the overall and percentage variations between 1995 and 2009 in the different categories of agricultural and woodland use in countries analysed in the present study are summarised. The category of the permanent meadows and pastures has been subject of small variations (1.20% in 15 years). The change in arable land, permanent crop and forestland seems more interesting. The former has sustained a loss of almost 34 million hectares, accompanied by an increase in woodland areas of 13 million hectares. These are significant events, especially in light of the policies that favour forestation implemented in several countries, also in relation to issues linked to climate change. They are an example of the forestry measures to favour forestation and this draws attention to the fact that the agricultural areas are also involved to varying degrees in the phenomenon of the expansion of the forested areas.

3. Econometric model

The analysis is carried out on a panel of 30 countries with upper middle or high income in the 1995-2009 period. The general model is based on the following equation

$$apc_{it} = a_{it} + bx'_{it} + \mu_i + \varepsilon_{it} \qquad (1)$$

where *apc* is the natural logarithm in arable and permanent crop land, x′ is a vector of conditioning variables which are related to the driving forces of agricultural land use change, μ is the error due to the individual effects and ε is the stochastic error. Pooled model, one-way and two-way fixed effects (FE) as well as random effects (RE) are applied. Different specifications have been tested using the usual tests (e.g. Hausman tests). The data used in the analysis are derived from the World Development Indicators (World Bank, 2010), the Penn World Table (Heston et al., 2011) and the FAO STAT website.

The area used to describe the evolution of agricultural land is composed by the sum of the areas destined to arable land and permanent crops (*apc*), since they represent the place where the majority of the value of agricultural production of a country is concentrated. In addition, these areas that can be converted to urban areas or woodland, depending on their position, or abandoned. In *apc* permanent meadows and pastures are not included, since these types of lands are placed in marginal territories, often in hilly or mountainous ones, far from areas destined to urban expansion. Moreover, precisely because of their position and the characteristics of the territory of which they are part, they are unlikely to undergo a re-conversion to agricultural land.

The specification used to describe the evolution of croplands in developed countries is based on 4 factors.

The first is the level of wealth reached by the country, which is defined through the per capita gross domestic product (*gdp*) expressed in natural log. This can also be observed in figure 1, where wealth is negatively related to agricultural land growth. Certainly the issue is complex and susceptible to many different interpretations. A possible interpretation could be that agricultural land is not considered an environmental resource with the same value as forests. Indeed, when the produced wealth increases, countries tend to implement programmes of protection and expansion of forests, but the same does not occur to agricultural land (at least based on existing statistics). This hypothesis leads to a predicted negative relationship between the gross fixed capital formation and agricultural land. Another hypothesis is that the policy instruments aiming at the protection of agricultural land as an environmental resource happen coincidentally in countries with high-income levels. This can be interpreted in light of the environmental Kuznets curve: agricultural land is a natural form of capital, for which the demand is activated by a level of income higher than that of forest areas. While in low-income countries deforestation is hindered by the increase in income level and the consequent shift of economical focus from the primary to the secondary sector, the use of agricultural land in high-income countries is curbed by the progressive shift of the economy to the advanced tertiary sectors and to the de-materialisation of processes and products. In light of this second hypothesis the relation between *gdp* and *apc* depends on the level reached by the economic system.

A second factor is the primary function of agricultural land: production of foodstuff and raw materials. The current process of market liberalisation drives towards an international sub-division of the production processes on the basis of its relative advantages. In this light, agricultural production is no longer tied to a particular territory, apart from those products benefitting of a geographical indication. Those products with a recognised geographical origin are protected particularly in the European Union and, for now, they constitute a fraction of the overall agricultural produce (Josling, 2006). The position of the agricultural sector in the economical system is described by the cereal yield (*cer_yield*) measured in tons of milled rice equivalent per hectare. This constitutes a proxy of the productivity of the agricultural sector. The increase in agricultural productivity observed in many developed countries over the last decades allows to maintain or to increase productivity levels over a smaller surface and gives the possibility of obtaining profit even alongside a decrease in prices. This is for instance the case of the process of liberalisation of markets for agricultural products. Those territories that are structurally unable to increase productivity tend to be abandoned or converted in forest areas, leading to the expectation of a negative relationship between productivity and agricultural surface.

The third factor influencing land use change is the tendency to form extensive urban structures that are tightly inter-connected. This factor describes the weight and the role of agglomeration economies (Rosenthal and Strange, 2004) in determining the conversion of the territory and urban development. Considering consolidated empirical results (Tabuchi, 1998; Glaeser and Kahn, 2003) we hypothesise that a settlement takes on a diffuse or concentrated form depending on the cost of transport and on the ease of movement. The expansion of the urban functions of the territory can therefore be evaluated basing on the dimensions and the level of use of road networks. This phenomenon is captured through the road sector energy consumption per capita (*road_en*), which constitutes a proxy of the level of use of the transport network and of the ease of movement of the population. As the level of use increases, the size of settlements and the dispersion of the production settlements across the territory increase. In addition, the push towards urbanisation is captured by considering the urban population living in the country's largest metropolitan areas (*lgst_city*), measured as a share of the country's population. Our hypothesis is that both these variables have a negative relationship to agricultural land, as they constitute a drive to expand the non-agricultural functions of the territory.

The last factor to be considered is the quality of institutions (*ruleoflaw*), which is included through the Rule of Law Index (Kaufmann et al., 2010). The debate on the conservation of agricultural land that has been developed in recent years both within the academic and civil societies has generated various forms of response by institutions. In particular, policies have spanned from those providing incentives toward the use of land resource and land use change, to the opposite end protecting conservation. In many countries, those programmes intending to protect agricultural land, which is considered a non-renewable environmental good, have widely spread (European Commission, 2006; American farmland Trust, 2009), although using different approaches and obtaining different results.

The quality of institutions has repercussions on the governance structures and on property rights, leading to the success or failure of land-use decision-making systems and processes of land-use planning, both at central level and at local government level (Keenleyside et al., 2099). Because of this, we expect a positive relationship between the Rule of the Law Index and agricultural land.

Table 3 provides a summary of the descriptive statistics of the variables. The next sections will present the results, analysing the observed relationships obtained from the regression analysis.

4. Results

Table 4 summarises the estimates obtained from various specifications. The preliminary two-way fixed effects estimate determines the importance of temporal effects. These do not appear to be significant: the F-test for the time effects fails to reject the null hypothesis of a joint elimination of year dummies (p-value=0.40).

The model with fixed effects highlights a predominance of variability in the individual effects on the residual and a low correlation between individual effects and explanatory variables. The standard errors of the estimations are smaller than those derived taking into account the temporal dummies, due to the greater efficiency gained through the reduction of parameters.

The F test supports the net rejection of the hypothesis of an absence of individual effects. To understand whether or not the specifications with fixed or random country-level effects are appropriate we tested the estimated GLS coefficients in the RE model and FE models and we compared them using an Hausman test. The test doesn’t rejects the hypothesis of absence of correlation between RE and the regressors of the model; therefore, the RE model provides more efficient estimates compared to the FE model.

In the RE model, the estimate θ=0.990 implies that GLS results are closer to the least squares dummy variable model (LSDV) than to the OLS. The Breusch-Pagan test confirms the incorrectness of a reliance on the pooled model. Then, the RE model is shown to be the one that best describes the relationship of interest.

In the RE model, all explanatory variables appear to be significant. The negative relationship between the explanatory variables and the dependent variable is verified, with the exception of the Rule of Law, which is positive as expected. This proves the starting hypothesis: the generation of wealth, the increase in agricultural productivity, the intensification of mobility and of urban agglomeration negatively influence the conservation of agricultural land, while strong institutions favour its protection. The relationship of agricultural land with explanatory variables can also be evaluated by focusing on Table 5, which indicates the effects of explanatory variables. The effects reported are in terms of elasticities which are evaluated at the sample regression means for explanatory variables.

On the basis of the model with random effects, the increase in one percentage point in gross domestic product produces a reduction in agricultural land (-0.13%), and this supports the hypothesis of the existence of an inverse correlation between wealth generation and agricultural area. With a p-value of 0.012, this correlation appears to be strongly significant.

The high level of significance of the *cer_yield* variable and the negativity of its coefficient lead us to conclude that a reduction in cropland with increasing productivity should not be overlooked. Marginal effect of *cer_yield* is -0.15%. As hypothesised, the increase in productivity have caused the abandonment or use change of lands whose productivity was unable to reward the economic value of all other factors employed.

Similarly, the effect caused by a rise in the proportion of population in metropolitan areas appears to be important. A percentage point increase in *lgst_city* reduces arable and permanent crop land by 2.26%, while a rise of 1% in energy consumption for mobility decreases *apc* by 0.12%.

The institutional quality plays a crucial role in the governance of rural areas and in land-use-planning. The Rule of Law variable is significant (p-value=0.019) and it is as expected positively correlated with agricultural land. The positive effect of institutions is reflected by an increase of 0.12% in the cropland following an increase of 1% in the Rule of Law index.

5. Conclusion

A number of conclusions can be drawn from the analysis conducted in this paper. In developed countries, the decrease in cropland that is currently taking place is caused by the expansion of forested areas, the urban expansion and the abandonment of the least productive areas. At least in terms of estimations at the global level, the evaluation of the end point for the remaining losses of agricultural land, between urbanisation and abandonment, is more complex.

The presence of abandoned and urbanised agricultural land highlights two phenomena: the loss of competitiveness of agriculture with respect to the international competition and the weakening of land revenue compared to urban rents. Both phenomena stem from the same fact: the inability of the agricultural sector to adequately reward investments made.

This in turns determines a change in land use, which takes on new directions depending on the specific context of the land. In peripheral areas, the abandonment of agricultural activity leads to formation of uncultivated areas or to conversion to forestland. This last process may occur spontaneously or it may be governed through a rational forest reconversion, also thanks to the agro-environmental programmes implemented by both the European Union and other countries.

In areas close to cities, the pressure applied by urban area-derived income, which in many cases is two orders of magnitude larger than that generated by agricultural land (Sali, 2009), is a strong incentive to convert agricultural lands into building lands. Good institutions and efficient land use planning strategy are able to control and govern this change.

At a global level, a re-equilibration of forest and agricultural lands between developing and developed countries is occurring. In the former, the forest surface decreases and the agricultural land increases, in the latter the opposite appears to be the case. This allows agricultural production to be localised where production costs are lower and the rising environmental demands in developed countries to be satisfied. Definitely, the phenomenon shows an economical coherence, but the consequences on food security and on the international political equilibrium still have to be evaluated. In this regard, an issue related to this phenomenon that requires further study is the so called “land grabbing” (FAO, 2009).

With regard to the possible inclusion of agricultural lands amongst environmental resources, the analysis leads to the conclusion that agricultural land is treated differently to forestland at this moment in time. While the latter is generally protected in most developed countries, the former is in constant decrease, despite the increase in the attention from public opinion and institutions in recent years. The analysis shows how the role of institutions is crucial to favouring a change in the process of cropland consumption: overall this process has not yet stopped, and agricultural land is still widely considered a resource to be exploited in generating other forms of capital, that are believed to have a higher economical or environmental value. A development of research may investigate which conditions favor the inclusion of agricultural land among environmental assets to be strongly protected.

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Fig. 1. Relationship between average annual change rate in arable and permanent crop land (1995-2009) and per capita GDP (1995) for a sample of 90 countries.

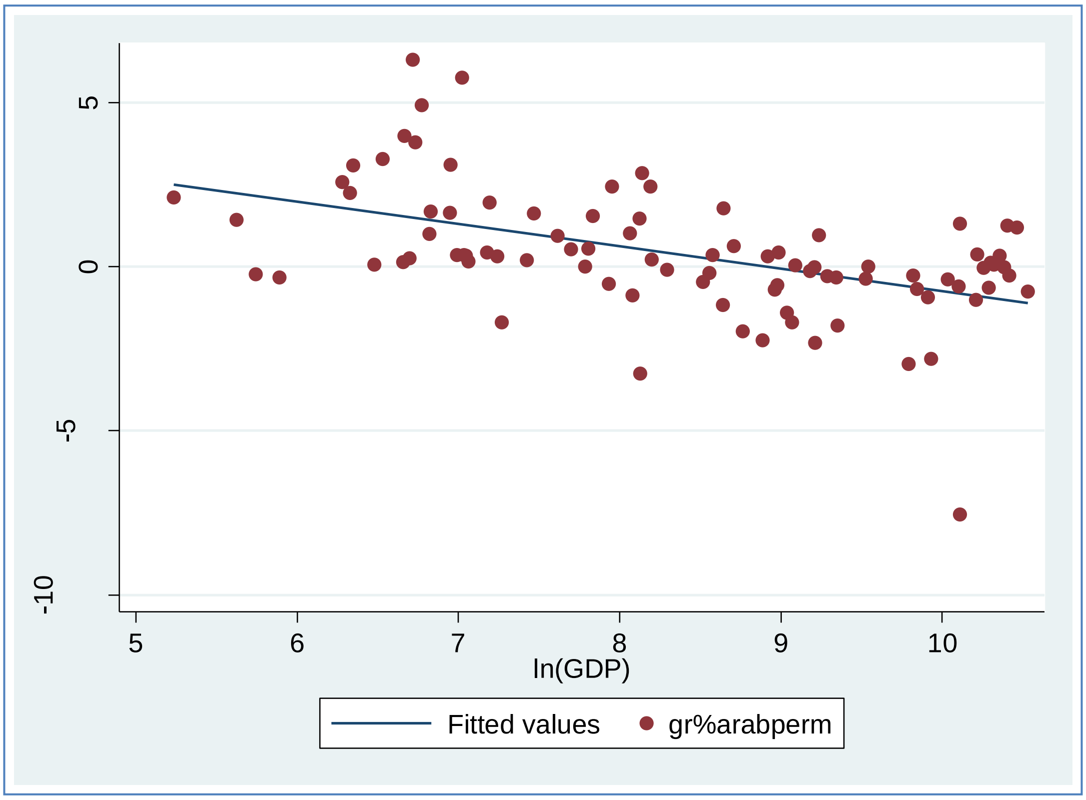

Table 1. Change in arable and permanent crop area according to income level from 1995 to 2009. All countries

	change in arable and permanent crop area (1000 ha)	change in arable and permanent crop area (share of land area)
Low income countries	25,614	1.48
Lower middle income	10,870	0.35
Upper middle income	-14,587	-0.31
High income	-14,805	-0.44

Source: World Bank, 2010

Table 2. Absolute and percentage change in land use between 1995 and 2009 in a sample of 30 countries

	Change	
	Absolute (1000 ha)	Percentage
Arable and permanent crops	-28,201	-7.37%
Forest area	13,281	1.78%
Permanent meadows and pastures	-4,277	-1.20%

The sample includes: Austria, Bulgaria, Canada, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Latvia, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovenia, Spain, Switzerland, Ukraine, United Kingdom, United States of America.

Table 3. Summary statistics of variables

Variable	Description	Obs	Mean	Std. Dev	Min	Max
apc Arable and permanent crop land (World Bank, 2010)	natural log of arable and permanent crop land	450	6.812	3.172	0.133	12.123
gdp Gross domestic product (Heston et al., 2010)	natural log of per capita GDP	450	9.919	0.587	8.185	10.842
cer_yield Yield of cereals (FAOSTAT, 2010)	tons of rice milled equivalent per hectare	450	4.546	1.826	0.900	9.032
lgst_city Urban population living in the country's largest metropolitan area (World Bank, 2010)	share of country's population	450	18.199	9.959	4.113	44.172
road_en Road sector energy consumption (World Bank, 2010)	kt of oil equivalent per capita	450	0.615	0.328	0.102	1.794
ruleoflaw Rule of Law index (Kaufmann et al., 2010)	no law=-2.5; full law=2.5	450	1.097	0.675	-1.072	1.964

Table 4. Panel analysis of arable and permanent crop area (*apc*), 1995-2009

Explanatory variables	Two-way fixed effects	Fixed effects	Random effects	Pooled
gdp	-0.148 *	-0.134 **	-0.135 **	-1.276 ***
	(0.002)	(0.054)	(0.054)	(0.474)
cer_yield	-0.046 ***	-0.035 ***	-0.034 ***	0.089 ***
	(0.013)	(0.012)	(0.012)	(0.004)
lgst_city	-0.127 ***	-0.122 ***	-0.124 ***	-0.134 ***
	(0.012)	(0.012)	(0.011)	(0.014)
road_en	-0.186	-0.203 *	-0.197 *	3.352 ***
	(0.122)	(0.120)	(0.119)	(0.568)
ruleoflaw	0.100 *	0.106 **	0.106 **	-0.822 **
	(0.052)	(0.045)	(0.045)	(0.393)
constant	10.838 ***	10.535 ***	10.581 ***	19.252 ***
	(0.825)	(0.484)	(0.712)	(4.276)
R-sq	0.25	0.25	0.25	0.33
N	450	450	450	450
Countries	30	30	30	
Estimation	Two-way FE	FE	RE	OLS
F-test	11.44 ***	40.44 ***		44.12 ***
Wald test (time dummies)	1.05			
Hausman test			1.67	
Breusch-Pagan (LM) test			3067.53 ***	

* Significant at 10% level; ** significant at 5% level; *** significant at 1% level
Standard error of coefficient indicated in parenthesis

Table 5. Elasticity effects of explanatory variables on dependent variable. Effects are calculated at the mean value of each variable.

	Elasticity effects
gdp	-0.135%
cer_yield	-0.155%
lgst_city	-2.257%
road_en	-0.121%
ruleoflaw	0.116%