Intelligence and economic sophistication

Athanasios Lapatinas^{1,2} · Anastasia Litina²

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Abstract

Backed by strong empirical results, obtained from several different specification and sensitivity analyses, this paper contends that countries with high-intellectual quotient populations produce and export more sophisticated/complex products. This result is further reinforced by the quality of democracy.

Keywords Intelligence · Economic sophistication · Complexity · Democracy · Institutions

JEL Classification F1 · A13 · D2 · B52

1 Introduction

Recent works by Hidalgo et al. (2007) and Hidalgo and Hausmann (2009) explain economic development and growth as a process of information development, a process of learning how to produce and export more complex products. In this paper, we argue that the development path of a country lies in its capacity to accumulate the “knowledge” part of the Robert Solow’s growth model. “Knowledge” is required to produce varied and more sophisticated goods; moreover, embedded in the countries’ productive structures, “knowledge” explains the differences in their economic performance (Rodrik 2006; Saviotti and Frenken 2008; Cristelli et al. 2015).

The question though is how “knowledge”-rich products and services are created in the economy. Hidalgo (2015) argues that what Kuznets called “measure of our ignorance” in his Nobel Prize acceptance speech is actually our individual mental capacity, our “personbytes”, or to put it broadly, our intelligence. A central function of the

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✉ Athanasios Lapatinas
athanasios.lapatinas@ec.europa.eu

¹ European Commission, Joint Research Centre, Via E. Fermi 2749, TP 361, 21027 Ispra, VA, Italy

² Department of Economics, University of Ioannina, P.O. Box 1186, 45110 Ioannina, Greece

economies then is to grind people's "personbytes" in producing sophisticated/complex products. And because such processes are enabled (or hindered) by inclusive (or extractive) institutions, the differences in the countries' capacities to chop up, process and reassemble their people's collective intelligence is what makes some countries more developed than others.

In this paper, we attempt to quantify the relationship between intelligence and sophistication. We empirically establish that collective intelligence is indeed related to a more sophisticated product space and that besides having a direct positive effect on economic growth (e.g., Weede and Kämpf 2002; Jones and Schneider 2006), intelligence has an indirect beneficial effect on a country's growth through the country's "knowledge"-endowment that is required to produce varied, sophisticated goods.

Furthermore, we find that this indirect effect is reinforced by the presence of democratic institutions. We explore the differential effect of intelligence on sophistication for different levels of institutions as motivated by the analysis in Hidalgo (2015) who emphasizes that different countries give different abilities to its people to develop, secure and organize the information they have. One plausible example is property rights, and how securing them allows one to further develop an idea or a patent. To make the example even more extreme, one can think of regimes in which some groups in the society, e.g., women or immigrants, do not even have access to an initial set of information that can lead to the further development of information and thus of more sophisticated structures or products. It is interesting to note that even in developed countries, such as Scandinavian countries, there is a huge effort to secure equal participation of men and women in the labor market. This is not only done for human rights purposes but it is also crucial for the smooth functioning of the economy and for exploiting all its available resources equally. Thus, institutional quality may make a difference to the speed of transition from the "personbyte," which is the individual capacity of a single individual to the "firmbyte," which indicates the knowledge distributed in a network of firms.

It is thus argued that the economic analysis should be interested not only in enhancing cognitive skills and information growth but also in how they interact with the functioning of economic and political institutions. This work has sobering messages for policy makers as well. First, that collective intelligence is necessary for economic development, through improving the diversity and refinement of the economy's export structure. Thus, identifying the policies that can raise collective intelligence is a first-order issue. Second, that the diverse effects of collective intelligence are larger in the presence of well-functioning institutions that govern all aspects of a country's economic and social life. Incentives arising from institutional functioning and economic policies are important accelerators of the accumulation of "knowledge" and of the extent to which existing human capital endowments are utilized in production.

The rest of the paper proceeds as follows; in Sect. 2, we discuss the relevant literature upon which we base our empirical analysis; in Sect. 3, we elaborate on a theoretical framework that links intelligence and sophistication; in Sect. 4, we discuss the empirical methodology and the data; in Sect. 5, we present the empirical results. Finally, Sect. 6 concludes.

2 Related literature

The aim of the paper is to empirically establish and to quantify the link between intelligence and product sophistication, a link that is totally unexplored in the existing literature. Second, we want to draw policy implications by arguing that the positive effect of intelligence is further reinforced by the presence of high institutional quality.

Starting from the topic of intelligence, the existing literature that employs intelligence as an explanatory variable is rapidly expanding recently and has come up with various diverse and interesting results.¹ A natural starting point was the positive link between intelligence and per capita real GDP as suggested by the pioneering studies of Lynn and Vanhanen (2002, 2006), who first compiled and used the intellectual quotient (IQ) data for several countries. They established that countries whose citizens have higher average scores on intelligence tests tend to be more economically developed, institutionally advanced and prosperous. This finding spurred economists to employ the IQ data in many subsequent published studies further investigating the relationship between intelligence and per capita income (e.g., Meisenberg 2004, 2009, 2012; Dickerson 2006; Rindermann 2008a, b, 2012; Jones and Schneider 2006; Templer 2008). Some researchers extended the analysis to explore the link between intelligence and economic growth (see e.g., Rindermann 2008a, b; Meisenberg 2012) also finding a positive relationship.

Another strand of the literature placed the spotlight on the interplay between intelligence and institutions. Several studies have established a positive correlation between intelligence and institutional development, democracy and economic/political freedom (see e.g., Meisenberg 2004, 2009; Rindermann 2008a, b; Jones 2011; Kanyama 2014).

Several other outcome variables have been linked to intelligence such as income inequality (Kanazawa 2009; Meisenberg 2012), education and literacy (Barber 2005), corruption (Meisenberg 2004, 2012; Potrafke 2012), savings (Jones and Podemska-Mikluch 2010), investment (Ram 2007), employment (Vinogradov and Kolvereid 2010), poverty (Kodila-Tedika and Bolito-Losembe 2014), financial development (Kodila-Tedika and Asonglu 2015), happiness (Stolarski et al. 2015), religiosity (Reeve 2009), liberalism (Kanazawa 2009) and entrepreneurship (Hafer and Jones 2015).

To summarize the spirit of the findings of the above-mentioned literature that employs the Lynn and Vanhanen measures of intelligence, it is overall argued that intelligence is a robust predictor of economic, social and political development as this is measured with a wide set of indicators. This result is robust across a large sample of countries.

On the other hand, and focusing on the topic of product sophistication, our contribution lies in bridging the intelligence literature with the literature that emphasizes the importance of economic complexity for the economy as a whole. The literature on economic complexity is another crucial literature that shows that the diversity, the number and the ubiquity of the products exported by a country are a good indicator of the level of sophistication of a country's productive structure.

¹ The associated literature is rather extensive. In this section, we provide an overview of only a fraction of this literature. In Appendix, we provide a more comprehensive list of papers that explore similar research questions but employ different methodologies/specifications.

The topic of economic complexity is a rather new one, and research studies on this area are rather limited so far, as well as its use in economics. The vast majority of the literature analyzes primarily the properties of the index (e.g., Hausmann and Hidalgo 2014; Albeaik et al. 2017a, b). There are few studies that have linked economic complexity with economic outcomes such as development, institutions and income inequality, suggesting that higher level of economic sophistication is associated with higher economic development (see e.g., Felipe et al. 2012; Caldarelli et al. 2012; Cristelli et al. 2015; Hausmann et al. 2007; Hidalgo et al. 2007)

Our study is the first one to bring together these two strands of literature and to empirically show that IQ is a significant determinant of product sophistication. To the extent that the creation of a new product embeds, among other things, not only the use of existing information but also the creation of new information, exploring whether IQ is a determinant of product sophistication arises naturally as a question worth pursuing. Crucially, we further show that even countries with high level of intelligence can benefit from the presence of good-quality institutions.²

3 Theoretical framework

As already mentioned in the section above, the literature that links IQ with a range of economic and social outcomes is quite widespread. What is less known is the measure of economic complexity that is reflecting the degree of economy's product sophistication and its economic implications.

Few things should be thus mentioned about this index that will crystallize the rational beyond empirically exploring the relationship between intelligence and sophistication. While the definition of the measure of economic complexity is rather simple (i.e., the diversity, the number, and the ubiquity of products a country exports, as already mentioned in the introduction), the actual measure is much more sophisticated than its definition. What is crucial is that what is embedded in this measure is information, i.e., accumulation of knowledge and know-how. For instance, each product an economy exports is associated with some level of complexity and sophistication that makes it unique. Moreover, it is not only the information that is embedded in a product that matters but also the order under which all this information is put together. Hidalgo (2015) characteristically mentions that an expensive car is not only a sum of its parts but also the way that these parts have been put together.

This is the “physics” behind information. However, there is also an economic part behind information and its implications. As it has always been the case in economics, the economic part lies in the fact that information is not free and is not limitless. It depends upon a multitude of factors, and this is what drives the differences between countries. It can depend upon human capital, natural resources, the institutional setting or geographical location. Thus, the economy's productive capacity depends on its ability to gather, combine and, perhaps, even secure all the necessary information needed to design and produce a product.

² The crucial role of institutions has been emphasized already in the economics literature (Acemoglu and Robinson 2012).

This intuition is what drives the first part of our empirical analysis. Given the information's importance for the production of complex goods and thus for an increase in the overall level of an economy's sophistication, we attempt to shed more light on its determinants. The IQ-related literature has found that it is linked to educational attainment, educational inputs and various cognitive outputs, like patents, scientific and technological excellence, academic publications, and Nobel prizes in science among other outcomes. All these are types of information that can lead to a high level of economic sophistication in terms of economy's productive capacity. Thus, exploring the link between the average level of intelligence and product sophistication seems like a natural place to start. Given that the correlation between IQ and all the above-mentioned outcomes is reported to be positive and robust, it can be plausibly assumed that IQ may confer a positive effect on the economy's level of sophistication. At the same time, the advantage of IQ is that it is a rather broad measure that encompasses most of the measures mentioned above. We can thus get a generalized result with many varying policy implications.

3.1 IQ as a determinant of economic complexity

Motivated by the theoretical discussion on the determinants of the index, in this subsection we model the hypothesis to be tested. To study the relationship between intelligence and product sophistication, we first construct the measure of economic sophistication (EXPY) using the framework developed by Hausmann et al. (2007). This index captures the productivity level associated with a country's export, i.e., it is a proxy for the most productive set of products the country can produce at a given time. In order to calculate the EXPY, index goods are ranked according to the income levels of the countries that export it. Products exported by prosperous countries are ranked higher than products exported by poor countries. The aggregation of these product-level calculations leads to the country-wide indexes of economic sophistication.

In detail, let us assume that j denotes the country and k the product. Then total exports of product k from country j equal:

$$X_j = \sum_k x_{jk} \quad (1)$$

If $(Y/L)_j$ denotes the per capita GDP of country j , the productivity level associated with product k equals the weighted average of per capita GDPs, where the weights represent the *Revealed Comparative Advantage (RCA)* of each country in that product:

$$\text{PRODY}_k = \sum_j \frac{\left(\frac{x_{jk}}{X_j}\right)}{\sum_j \left(\frac{x_{jk}}{X_j}\right)} (Y/L)_j \quad (2)$$

Then, the PRODY metric can be used to compute the productivity level associated with country i 's economic sophistication, EXPY_i , as the average income and productivity level associated with all products exported by a country. It is computed as the

weighted average of all relevant PRODYs, where the weights represent the share of the relevant product in the country's export basket:

$$\text{EXPY}_i = \sum_k \left(\frac{x_{ik}}{\bar{X}_i} \right) \text{PRODY}_k = \sum_k \sum_j \frac{\left(\frac{x_{ik}}{\bar{X}_i} \right) \left(\frac{x_{jk}}{\bar{X}_j} \right)}{\sum_j \left(\frac{x_{jk}}{\bar{X}_j} \right)} (Y/L)_j \quad (3)$$

Having derived the equation for the economic sophistication index, EXPY_i , we want to link this index with the average IQ level. Thus, following Jones and Schneider (2010), we assume the IQ-augmented Cobb–Douglas production function:

$$Y_j = (K_j)^a \left(e^{\gamma \text{IQ}_j} A_j L_j \right)^{1-a} \quad (4)$$

where j is the country; Y , K , A and L are output, the capital stock, technology, and the labor supply, respectively; γ is the impact of IQ on human capital. Reorganizing the production function, we get:

$$\left(\frac{Y}{L} \right)_j = A_j e^{\gamma \text{IQ}_j} \left(\frac{K}{Y} \right)_j^{\frac{\alpha}{1-\alpha}} \quad (5)$$

This is the equation derived by Jones and Schneider (2010) to evaluate the impact of IQ differences on steady-state living standards. As the authors argue (p. 748), writing the equation in this way is useful since in a Solow or Ramsey growth model, the steady-state capital-output ratio is independent of the level of technology and by extension, the level of IQ (see also Jones and Podemska-Mikluch 2010). The relationship between national average IQ and national productivity has been investigated empirically by Lynn and Vanhanen (2002) and Jones and Schneider (2006). The first paper finds a correlation coefficient of 0.7 between national average IQ and the level of GDP per worker in 81 countries. The respective coefficient in Jones and Schneider (2006) is 0.82 in a 455 cross-country growth regressions analysis (à la Sala-i-Martin et al. 2004).

Substituting the last equation in Eq. (3), we get:

$$\text{EXPY}_i = \sum_k \sum_j \frac{\left(\frac{x_{ik}}{\bar{X}_i} \right) \left(\frac{x_{jk}}{\bar{X}_j} \right)}{\sum_j \left(\frac{x_{jk}}{\bar{X}_j} \right)} (Y/L)_j = \sum_k \sum_j \frac{\left(\frac{x_{ik}}{\bar{X}_i} \right) \left(\frac{x_{jk}}{\bar{X}_j} \right)}{\sum_j \left(\frac{x_{jk}}{\bar{X}_j} \right)} A_j e^{\gamma \text{IQ}_j} \left(\frac{K}{Y} \right)_j^{\frac{\alpha}{1-\alpha}} \quad (6)$$

This is the equation that qualitatively delivers the link between IQ and steady-state sophistication of exported products. Building upon this intuition, we formulate the main hypothesis to be tested in the paper. We thus empirically test the hypothesis that two countries that differ only in average IQ—everything else being constant across countries (*ceteris paribus*)—manifest differences in economic sophistication. That is, if one of the two countries moves to a higher IQ level, in the steady-state, economic sophistication would be greater in the higher IQ country.

The following section describes analytically the data and formally sets the equation to be tested which is augmented by additional controls that correlate with the measure of economic sophistication.

4 Data and estimation strategy

We measure economic sophistication in year 2010 using the respective value of the Economic Complexity Index (ECI) available at the MIT's Observatory of Economic Complexity (<https://atlas.media.mit.edu/rankings>), which is calculated according to Hidalgo and Hausmann's (2009) economic complexity formula. The ECI is a measure of diversity and sophistication of a country's export structure (Hausmann and Hidalgo 2014). The ECI captures information about an economy's level of development that is different from that captured, for example, by the measures of GDP growth or per capita GDP.

To illustrate this difference, Fig. 1 compares the product structures of the economies of Chile and Ecuador with those of Malaysia and Thailand, respectively (see also the discussion in Hartmann et al. 2017). When comparing the countries in terms of GDP per capita (source: World Development Indicators, World Bank), the economies of Chile (\$18,256 at PPT in current 2011 US\$) and Ecuador (\$9163) are similar to the economies of Malaysia (\$20,675) and Thailand (\$13,309), respectively, but their productive structures differ significantly. Analytically, Chile and Ecuador largely export natural resources, raw materials and agricultural products, while, in contrast, Malaysia and Thailand export a diverse spectrum of electronic parts, peripherals and accessories as well as machinery, like trucks and cars. The ECI captures these differences in productive structures, assigning higher values to the more sophisticated, diversified and complex economies of Malaysia and Thailand (in 2010, Malaysia ranked 32nd while Chile ranked 68th and Thailand ranked 28th while Ecuador ranked only 95th).

Following a series of papers mentioned in the related literature section and in Appendix [e.g., Weede and Kämpf (2002) and Hafer and Jones (2015) among others], we measure *Intelligence* using the IQ data by Lynn and Vanhanen (2006) and Lynn and Meisenberg (2010). In the baseline results, we use the data by Lynn and Vanhanen (2006), so as not to allow simultaneity to kick in. However, this is not crucial and in the robustness section we use the data for the year 2010, where our results remain intact.

The nature of the data is such that it does not allow exploiting any time variation. While in general it is true that when it comes to IQ scores they might evolve upward overtime this takes place over very large periods, e.g., two or three generations difference, a time span that is not covered by the existing dataset. Analytically, there are three sources of data for IQ, i.e., (a) Lynn and Vanhanen (2002) (b) Lynn and Vanhanen (2006) and (c) Lynn and Meisenberg (2010). Each dataset simply extends the previous version of the data from 81 countries that were initially published in 2001 and 2002, to 113 countries in 2006 and a total of 136 countries in 2010. Thus, any changes are related to the number of countries included in the sample and *not in changes* in the IQ of the existing countries. This is the reason why our study, like all the above-mentioned studies, exploits the cross-country nature of the data.

Fig. 1 (Colored) Export structure of Malaysia **(a)**, Chile **(b)**, Thailand **(c)** and Ecuador **(d)** in 2010. *Source:* <https://atlas.media.mit.edu>

Table A.1 in Appendix illustrates the summary statistics of the sample in the benchmark analysis, i.e., for 108 countries for which the full set of benchmark controls is available. The ECI index in our sample takes values from -2.38 to 2.10 , while the average IQ takes values from 64 to 108 . It includes several low- and high-income countries. (The high values are due to the fact that we use PPP measure of GDP, essential for meaningful comparisons.) Similarly, we have a wide range of countries with respect to institutional quality that includes both democracies and dictatorships.

Figure 2 shows that *Intelligence* is positively associated with *Sophistication* with a correlation coefficient between ECI and IQ at 0.77 . Countries with high IQ populations and high product sophistication include Japan, Singapore and Switzerland.

To ensure robust econometric identification, we use a number of control variables in the estimated equation. More precisely, we control for the overall level of productivity and wealth in the economy by employing real (log) GDP per capita (*Log GDP per capita*) from the World Bank's World Development Indicators and for the year 2010. We also control for countries' institutional differences using the *Polity* democracy index from the Polity IV database, for the year 2010 (Marshall and Jaggers 2002). In addition, we employ ethno-linguistic fractionalization by employing the Alesina et al. (2003) data on *Ethnic Diversity* and *Linguistic Diversity*. Finally, we employ *Openness* (imports plus exports as percentage of GDP for the year 2010 from the World Bank's World Development Indicators) to account for international market integration. We also include a set of *Geographical dummies* for Africa, Europe, Oceania, North and South America and Asia so as to capture continental differences.

Importantly, we introduce each set of controls gradually, in columns (1)–(6) of Table 1, to study the evolution of the coefficient. Controlling for GDP and *Polity* causes a big drop in the coefficients, a result that is anticipated as these are two very

Fig. 2 Sophistication and intelligence

crucial controls that capture a large fraction of differences. Any additional controls do not significantly change the magnitude of the coefficient, thus suggesting that most of the unobserved heterogeneity has already been captured by the first two controls. This is further reinforced by the fact that the adjusted R -squared also remains rather constant beyond the introduction of the first two controls, even after controlling for the continental fixed effects. In line with the method suggested by Oster (2014), that takes into account both the evolution of the coefficient and of the R -squared, most of the unobserved heterogeneity is already captured by the two main controls. To further explore unobserved heterogeneity, we conduct another formal test suggested by Frank et al. (2013). The results of this test suggest that to invalidate our inference regarding the effect of IQ on ECI one would have to replace more than 80% of the sample in our study, and assume the limiting condition of zero effect of IQ in the replacement cases. We are thus reassured that our analysis is not plagued by unobservables.

The baseline specification used to study the relationship between *Intelligence* and *Sophistication* has the following form:

$$\begin{aligned} \text{Sophistication}_i = & \alpha_0 + \beta_1 \text{Intelligence}_i + \beta_k \text{controls}_i \\ & + \text{geographical dummies}_i + u_i \end{aligned} \quad (7)$$

Table 1 Sophistication and intelligence: benchmark results

<i>Dependent variable:</i> Sophistica- tion	(1)	(2)	(3)	(4)	(5)	(6)
Intelligence	0.070*** (0.006)	0.047*** (0.008)	0.039*** (0.007)	0.034*** (0.008)	0.033*** (0.008)	0.030*** (0.010)
Log GDP per capita		0.314*** (0.073)	0.329*** (0.068)	0.328*** (0.066)	0.325*** (0.068)	0.329*** (0.068)
Polity			0.032*** (0.007)	0.031*** (0.007)	0.032*** (0.007)	0.035*** (0.011)
Ethnic diversity				−0.566* (0.332)	−0.574* (0.329)	−0.391 (0.316)
Linguistic diversity				0.225 (0.243)	0.192 (0.251)	0.051 (0.257)
Openness					0.001 (0.001)	0.001 (0.001)
Geographical dummies	No	No	No	No	No	Yes
Observations	108	108	108	108	108	108
R-squared	0.603	0.683	0.726	0.735	0.737	0.774

Robust standard errors in parentheses. The *, ** and *** marks denote statistical significance at the 10, 5 and 1%, respectively

where the subscript i refers to country i . All regressions are estimated with Ordinary Least Squares (OLS). We also include robust standard errors to correct for heteroscedasticity.³

5 Results

5.1 Basic results

Table 1 shows the baseline results. In column (1), we simply regress *Sophistication* on *Intelligence*. The correlation coefficient is positive and highly significant (at the 1% level). This result indicates that economies characterized by higher *Intelligence* produce and export more sophisticated products. Column (2) introduces a control for income per capita (log). This captures large differences in income across countries as well as several qualitative differences. Indeed, as anticipated this control bears a positive and highly significant coefficient indicating that richer countries tend to produce more complex products. Moreover, the coefficient of *Intelligence* drops significantly, thus verifying that income per capita is an important control capturing a large fraction of the unobserved heterogeneity. Column (3) introduces *Polity*, a control that captures

³ Conducting the Breusch–Pagan test, we can reject the null hypothesis for homoscedasticity at the 5% level and thus we correct for heteroscedasticity by obtaining the White-corrected robust variance estimates.

institutional quality (Marshall and Jaggers 2002). The sign of the coefficient is also positive and highly significant (at 1% level), highlighting the positive effect of political institutions on a country's productive structure. This result is in line with the theory that goes back to the writings of Lewis (1954), Rostow (1959), Kuznets and Murphy (1966), Kaldor (1967), Chenery and Taylor (1968) where the development and growth of nations is viewed as a process of structural transformation of their economies' productive structure and it is recently revived and extendible emphasized by Acemoglu and Zilibotti (1999), Acemoglu and Robinson (2012), Hidalgo et al. (2007), Hidalgo and Hausmann (2009), among others. Moreover, the coefficient of *Intelligence* further drops, thus suggesting that institutional quality is another crucial control variable.

Column (4) introduces two measures of diversity, namely ethnic and linguistic diversity. The only measure that comes as significant is the measure of ethnic diversity which is significant at the 10% level and has a negative coefficient. This implies that higher diversity is associated with lower economic sophistication, potentially due to the fact that higher ethnic diversity is associated with lower cooperation and lower quality of institutions which can harm the productive structure of the economy. The other control is insignificant. Importantly, we observe that the coefficient of *Intelligence* remains relatively intact and so does the adjusted *R*-squared, which implies that most of the unobserved heterogeneity has already been captured by the previous controls introduced in columns (2) and (3). Column (5) enriches the analysis with a measure for the degree of country's openness. The coefficient is nonsignificant, and the coefficient for *Intelligence* remains rather stable. Last, column (6) controls for a set of continental fixed effects which should capture the large differences across continents. However, the results remain rather unchanged, and thus we are reassured that the positive effect of *Intelligence* on *Sophistication* remains even after controlling for a large number of controls and unobservables. The results in column (6) will be henceforth mentioned as the *benchmark* specification that accounts for the full set of controls. It should be noted that the number of observations has been stabilized to 108 countries for which we have observations for all controls. We are thus reassured that our results are not driven by changes in the sample.⁴

Table 2 provides some additional results that shed more light on the quantitative importance of our results. Column (1) of Table 2 replicates the analysis in column (6) of Table 1. The difference is that it reports the standardized betas. We obtain two types of information from this specification. First, the beta coefficient is 0.337 suggesting that one standard deviation change in the measure of *Intelligence* is associated with a 0.337 change in the standard deviation of the measure of *Sophistication*. To further quantify the result in terms of the actual ranking, a 10-unit change in the measure of IQ (that takes values from 64 to 108, with standard deviation 10.8) is associated with a 0.34 change in the ECI measure (that takes values from −2.4 to 2.1, with standard deviation 0.975), which is a non-trivial effect. Second, the beta coefficients allow us to compare the differential effect of each factor. Interestingly, we can see that the effect is slightly lower to that of per capita GDP (where a unitary change in the standard deviation of GDP is associated with a 0.402 change in the standard deviation of the

⁴ From a previous version of the paper, it is clear that the results hold even for a larger set of countries. In the robustness section, we will also allow greater flexibility as to the number of countries.

Table 2 Sophistication and intelligence: quantification of the results

<i>Dependent variable:</i> Sophistication	(1)	(2)
Intelligence	0.337*** (0.010)	
Intelligence (low-sophistication countries)		0.021*** (0.007)
Intelligence (high-sophistication countries)		0.030*** (0.007)
Log GDP per capita	0.402*** (0.068)	0.254*** (0.053)
Polity	0.243*** (0.011)	0.131** (0.009)
Ethnic diversity	−0.095 (0.316)	−0.081 (0.237)
Linguistic diversity	0.014 (0.257)	0.010 (0.172)
Openness	0.011 (0.001)	−0.014 (0.001)
Geographical dummies	Yes	Yes
Beta coefficients	Yes	Yes
Observations	108	108
R-squared	0.774	0.857

Column (1) replicates the analysis in column (6) of Table 1 and reports the standardized betas. Column (2) replicates the analysis in column (6) of Table 1, by estimating the effect separately for countries with high and low levels of product sophistication. Robust standard errors in parentheses. The *, ** and *** marks denote statistical significance at the 10, 5 and 1%, respectively

ECI) and stronger than the effect of institutions (where a unitary change in the standard deviation of Polity is associated with a 0.243 change in the standard deviation of the ECI).

Column (2) of Table 2 replicates the benchmark analysis by estimating the effect separately for countries with high and low levels of product sophistication. (Each group contains a similar number of countries, i.e., 50 and 58 countries, respectively.) Our findings suggest that the effect of IQ is positive and highly significant for both groups of countries. As to the magnitude of the effect, it is quite similar to that described in column (1). Interestingly, the effect is stronger for countries with high level of product sophistication, i.e., the effect of *Intelligence* is further reinforced in high-sophistication countries. It should be noted though that the difference is not very pronounced.

5.2 Robustness checks

In this section, we establish the robustness of our results to alternative specifications.

Table 3 Sophistication and intelligence: robustness to the use of alternative ECI measures

	(1)	(2)	(3)
Intelligence	0.031 ^{**} (0.012)	0.034 ^{***} (0.009)	0.039 ^{***} (0.007)
Log GDP per capita	0.196 ^{**} (0.092)	0.315 ^{***} (0.060)	0.227 ^{***} (0.078)
Polity	0.054 ^{***} (0.014)	0.038 ^{***} (0.010)	0.026 [*] (0.013)
Ethnic diversity	− 0.118 (0.388)	− 0.408 (0.285)	− 0.685 ^{**} (0.287)
Linguistic diversity	− 0.563 ^{**} (0.267)	− 0.078 (0.232)	0.248 (0.228)
Openness	0.001 (0.001)	0.000 (0.001)	− 0.000 (0.001)
Geographical dummies	Yes	Yes	Yes
Observations	73	110	110
R-squared	0.768	0.683	0.733

Dependent variable: ECI in the year 2013 (column 1); updated ECI (column 2); improved ECI (ECI+) (column 3). Robust standard errors in parentheses. The *, ** and *** marks denote statistical significance at the 10, 5 and 1%, respectively. We estimate robust standard errors

5.2.1 Robustness to the use of different ECI measures

First, we establish the robustness of our results to the use of alternative measures of ECI. Column (1) of Table 3 uses as the dependent variable the measure of ECI in the year 2013 (last available year). In this column, we also employ the Lynn and Meisenberg (2010) IQ data. As in the benchmark specification, we use the IQ measure with a lag so as not to allow for simultaneity to kick in. Column (2) replicates the benchmark analysis by introducing an updated measure of the ECI for the year 2010. (The updated ECI dataset was downloaded from MIT's Observatory of Economic Complexity on October 2017; <https://atlas.media.mit.edu/en/>.) Column (3) uses the measure of ECI+ introduced in Albeaik et al. (2017a), which is a simpler metric that measures the total exports of an economy corrected by how difficult it is to export each product. Furthermore, the definition of ECI+ is equivalent to the Fitness complexity metric proposed by Tacchella et al. (2012).⁵ All three columns in Table 3 introduce the full set of controls used in the benchmark specification and do not restrict the sample so as to verify the results for the larger sample possible. In all three columns, our findings are robust and in line with those in the benchmark specification.

5.2.2 Robustness to additional controls and outliers

Table 4 establishes the robustness of the analysis to the use of additional controls so as to capture an even larger number of unobservables. Even though the benchmark

⁵ See the discussion in Albeaik et al. (2017a).

Table 4 Sophistication and intelligence. Robustness to additional controls and outliers

	(1)	(2)	(3)	(4)	(5)
Intelligence	0.032*** (0.012)	0.022*** (0.008)	0.029*** (0.009)	0.027*** (0.008)	0.041*** (0.010)
Log GDP per capita	0.353*** (0.094)	0.347*** (0.060)	0.133 (0.088)	0.163 (0.122)	0.345*** (0.065)
Polity	0.038*** (0.011)	0.010 (0.013)	0.014 (0.013)	0.011 (0.013)	0.048*** (0.010)
Ethnic diversity	− 0.271 (0.291)	− 0.347 (0.288)	− 0.285 (0.271)	− 0.207 (0.267)	− 0.196 (0.295)
Linguistic diversity	0.065 (0.273)	− 0.092 (0.240)	− 0.118 (0.213)	− 0.035 (0.213)	0.017 (0.300)
Openness	− 0.001 (0.002)	0.000 (0.001)	− 0.001 (0.001)	− 0.002 (0.002)	0.000 (0.001)
Secondary enrollment	0.001 (0.004)				
Tertiary enrollment	− 0.001 (0.005)				
Legal Origin (UK)		0.697*** (0.205)		0.385* (0.202)	
Legal Origin (FR)		0.540*** (0.170)		0.520*** (0.192)	
Legal Origin (GE)		0.424** (0.163)		0.234 (0.172)	
Legal Origin (SC)		0.623** (0.255)		0.368 (0.307)	
Legal Origin (Socialist)		0.449 (0.307)		0.289 (0.304)	
KOF Index			0.026*** (0.007)	0.021** (0.008)	
Shadow			0.002 (0.003)	− 0.001 (0.004)	
Religious diversity			0.460** (0.214)	0.087 (0.239)	
Geographical dummies	Yes	Yes	Yes	Yes	Yes
Observations	98	108	108	98	108
R-squared	0.801	0.812	0.825	0.844	

Dependent variable: sophistication. Robust standard errors in parentheses. The *, ** and *** marks denote statistical significance at the 10, 5 and 1%, respectively

analysis and the works by Oster (2014) and Frank et al. (2013) suggest that unobservables do not drive the results, we introduce some additional controls here to test the robustness of our analysis.

Column (1) starts from the benchmark specification with the full set of controls and introduces two measures for secondary and tertiary education from the World Bank's

World Development Indicators. In column (2), we include the *Legal Origin* dummy variables taken from La Porta et al. (1999). In column (3), we add further control variables, namely *Religious Diversity* from Alesina et al. (2003), the *KOF Index* of globalization (Dreher 2006; Dreher et al. 2008) and the size of the *Shadow* economy from Dreher and Schneider (2010). Adding all these controls together in column (4) leaves our empirical findings qualitatively intact.

Last, in column (5), in Table 4, we examine the robustness of our benchmark results by checking whether these are driven by individual outliers and by applying robust regression techniques. Outliers are observations that lie outside the typical relationship between the dependent and explanatory variables determined by the rest of the observations (Barnett and Lewis 1994; De Haan and Ferreira 2007). The standard practice is dropping observations identified as outliers through the residuals of the OLS estimation. However, this may in fact be inappropriate: outliers in the space of the explanatory variables (i.e. “good leverage points”, Rousseeuw and Leroy 2005) are not detected by this method. In order to deal with this issue, we apply robust regression techniques. Specifically, we employ the MM-estimator (Yohai 1987). Following Rousseeuw and Yohai (1984), this class of estimators instead of minimizing the variance of the residuals (as OLS does) minimizes measures of dispersion of the residuals that are less sensitive to outliers. As can be seen in column (5), our empirical findings remain highly robust under robust regression techniques.

5.2.3 Robustness to the use of different measures of institutional quality

Table 5 establishes the robustness of our results to the use of alternative measures of institutional quality. In column (1), we replicate the analysis in column (6) of Table 1 just for comparison. Here, we use the measure of *Polity* from the Polity IV project. In column (2), we use instead the new democracy-dictatorship data from Cheibub et al. (2010). In column (3), we introduce the measure of constraints on the executives also coming from the Polity IV dataset. Last, in column (4) we use the measure of rule of law coming from the World Bank’s Worldwide Governance Indicators. In all four columns, we have the full set of controls as in the benchmark specification and we simply replace the measure of institutional quality. The results remain qualitatively and quantitatively intact.

5.3 The effect of democracy on the nexus between intelligence and sophistication

In this subsection, we place the spotlight on the potential differential effect of the democracy on the nexus between intelligence and sophistication. To identify this channel, we alter Eq. (7) to introduce the interaction term *Intelligence * Polity*. We split the sample in three (column (1) of Table 6) or four (column (2) of Table 6) categories based on the *Polity* indicator. Each category contains a set of countries with similar political regime. This approach allows us, first, to see the interaction between institutional quality and intelligence, as well as to quantify the result for different levels of institutions. We observe that in both columns (i.e., for both types of classification of countries according to their institutional quality) the effect of intelligence becomes

Table 5 Sophistication and intelligence. Robustness to alternative measures for institutions

	(1)	(2)	(3)	(4)
Intelligence	0.030*** (0.010)	0.033*** (0.010)	0.030*** (0.010)	0.028*** (0.010)
Polity	0.035*** (0.011)			
Democracy (Cheibub)		− 0.001 (0.005)		
Executive constraints			0.121*** (0.034)	
Rule of law				0.392*** (0.070)
Geographical dummies	Yes	Yes	Yes	Yes
Observations	108	108	107	108
R-squared	0.774	0.754	0.778	0.795

Dependent variable: sophistication. Robust standard errors in parentheses. The *, ** and *** marks denote statistical significance at the 10, 5 and 1%, respectively

stronger as institutional quality improves. We thus find a positive nexus between intelligence and institutional quality. For instance, in column (1) the stronger effect is traced for countries that have quality of institutions higher than 6, i.e., for countries such as all EU countries but also countries like Panama, Senegal or Kenya with a good (but not perfect) quality of institutions. Similarly, for column (2), the stronger effect takes place for countries with institutional quality larger than 3 in the *Polity* scale, i.e., a classification that also includes countries (besides EU countries) such as Zambia, Suriname or Nigeria.

The underlying mechanism could be associated with the fact that in a well-functioning democracy or at least in a country with a decent level of institutions there is the necessary social and political framework that allows for the full exploitation of the benefits arising from a high average IQ at the population level. This positive “endowment” is further enriched and can be fully converted into a higher level of sophistication in the economy.

This is a very interesting result with important policy implications as it suggests that policy makers should not only aim to advance policies that raise the aggregate intelligence level but also to policies that improve institutional quality.

An additional observation is that at all levels of institutional quality, all economies can benefit from a higher level of intelligence, i.e., the positive correlation between intelligence and sophistication is valid for all regimes.

6 Conclusions

Our study documents a positive relationship between national estimates of cognitive skills [approximated here by the IQ series published by Lynn and Vanhanen (2006)

Table 6 Sophistication and intelligence. Interaction with institutions

	(1)	(2)
Intelligence—institutions (− 10 < Polity < − 5)	0.030*** (0.010)	
Intelligence—institutions (− 4 < Polity < 0)	0.035*** (0.010)	
Intelligence—institutions (1 < Polity < 5)	0.033*** (0.010)	
Intelligence—institutions (6 < Polity < 10)	0.036*** (0.010)	
Intelligence—institutions (− 10 < Polity < − 5)		0.030*** (0.010)
Intelligence—institutions (− 4 < Polity < 2)		0.034*** (0.010)
Intelligence—institutions (3 < Polity < 10)		0.037*** (0.011)
Geographical dummies	Yes	Yes
Controls	Yes	Yes
Observations	108	108
R-squared	0.775	0.774

Dependent variable: sophistication. Robust standard errors in parentheses. The *, ** and *** marks denote statistical significance at the 10, 5 and 1%, respectively

and Lynn and Meisenberg (2010)] and product sophistication (using the values of the respective index from MIT's Observatory of Economic Complexity). Our paper attempts to link these two strands of literature. Our findings suggest a positive correlation between the level of a country's collective intelligence and the level of its economic sophistication. Our benchmark analysis controls for a wide set of variables and is robust to a number of alternative specifications. Our analysis is further enriched by exploring the role of democracy as a catalyst on the nexus between intelligence and sophistication.

Our findings can yield interesting policy implications. First, they hint to the fact that employing policies that can raise collective intelligence is a first-order issue as it can improve the productive capacity and level of sophistication in an economy. An example would be to increase investment in education as well as to foster qualitative changes in education that advance creativity and can thus contribute to raising collective intelligence. For instance, it has been shown that at the individual level, one extra year of schooling can increase IQ by 1.5–2 units.

Second, they highlight another dimension along which well-functioning institutions can contribute to a country's overall efficiency. Improving institutional quality can operate via several distinct channels one of which is improving the level of the economy's product sophistication. Product sophistication reflects among other things the ability to create and document information. A typical example would be property rights and the associated incentives to develop innovative products. It is self-evident

that living in a regime with good-quality institutions greatly enlarges the possibility to create and develop new information/knowledge and thus to raise the economy's level of sophistication.

Overall, by bringing together these two strands of literature we aspire to link the interesting measure of complexity to the economics literature and to contribute one more determinant that can enhance the level of sophistication of the economy.

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