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The effect of the Internet on economic sophistication: An empirical analysis

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HIGHLIGHTS

- The paper studies the effect of the Internet on economic sophistication.
- The Internet is measured as the percentage of individuals using the internet in total population.
- Economic sophistication is measured with the improved Economic Complexity Index.
- The Internet has a positive effect on economic sophistication.

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ABSTRACT

Backed by empirical results obtained from dynamic panel data analysis, this letter contends that the Internet has a positive effect on the sophistication of exported products after controlling for potential covariates.

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1. Introduction

A number of recent contributions explain economic development and growth as a process of information development and of learning how to produce and export more sophisticated products (Abdon and Felipe, 2011; Bustos et al., 2012; Caldarelli et al., 2012; Cristelli et al., 2013, 2015; Felipe, 2012; Hausmann et al., 2007, 2014; Hidalgo and Hausmann, 2009; Hidalgo et al., 2007; Tacchella et al., 2013; Albeaik et al., 2017b; Saviotti and Frenken, 2008). These contributions have introduced an elaborate metric called the Economic Complexity Index (*ECI*) that quantifies the amount of knowledge materialized in a country's productive structure (Hausmann et al., 2007, 2014; Hidalgo and Hausmann, 2009; Hidalgo et al., 2007). In recent years, the *ECI* has received widespread attention throughout the scientific community, with most specialists agreeing that economic sophistication accelerates economic growth (Hidalgo and Hausmann, 2009; Hausmann and Hidalgo, 2011). The literature on economic complexity shows that the diversity, number and ubiquity of the products exported by a country are good indicators of its level of development. However, the topic of economic complexity is a rather new one and economic studies in this area are limited so far. For example, the determinants of economic complexity still remain unexplored in the economics literature. Only a few very recent papers are available on this topic, such as Hartmann et al. (2017), which shows that countries exporting complex products tend to be more inclusive and have lower levels of income inequality than countries exporting simpler products, and Lapatinas and Litina (2018), which finds that countries with high intellectual quotient (IQ) populations produce and export more sophisticated/complex products.

In contrast, the influence of the development and expansion of internet access around the world on many aspects of economic development is well known. Internet access has been shown to have significant positive impacts on economic growth (Choi and Yi, 2009; Sichel, 1999), productivity (Oliner and Sichel, 2000; Oliner et al., 2007; Gust and Marquez, 2004), foreign direct investment (Choi, 2003), and trade (Lin, 2015; Freund and Weinhold, 2002, 2004; Blum and Goldfarb, 2006; Clarke and Wallsten, 2006;

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Vemuri and Siddiqi, 2009; Choi, 2010), and negative effects on inflation rates (Yi and Choi, 2005).

Our study is the first to bring together these two strands of literature and to empirically show that the Internet has a significant positive effect on product sophistication. In view of the fact that the creation of new products involves the use of both existing and new information/knowledge, the research question "What is the effect of the Internet on economic sophistication?" naturally arises. This letter aims to bring the interesting methodology of economic complexity in the economics literature showing that besides having a direct positive effect on economic development, internet usage also has an indirect positive effect through the sophistication of production.

2. Model

We study the effect of the Internet on economic sophistication using the datasets described in Section 3. Given the availability of instruments and controls, the sample covers 100 developed and developing countries over the period of 2004–2015.

We regress the baseline specification described by the following equation:

$$\mathrm{ECI}_{i,t} = \alpha \mathrm{ECI}_{i,t-1} + \beta_1 internet_{i,t} + \beta_k controls_{i,t} + \gamma_i + \delta_t + u_{i,t}. \quad (1)$$

Here, the economic sophistication of country i in period t ($ECI_{i,t}$) depends on a country's *internet* usage, which is the key regressor of our analysis (the parameter β_1 measures the effect of the internet on economic sophistication). The lagged dependent variable on the right-hand side is included to capture persistence in economic sophistication. To ensure robust econometric identification, we use a number of *control* variables described in the next section. In addition, the γ_i's denote a full set of country dummies and the δ_t's denote a full set of time effects that capture common shocks to economic sophistication level of all countries. $u_{i,t}$ is the error term capturing all other omitted factors, with $E(u_{i,t}) = 0$ for all i and t.

The question that arises is whether internet usage as a determinant of economic sophistication can be treated as plausibly exogenous. In other words, can the relationship between the Internet and economic sophistication be interpreted as causal? It could well be that the production of sophisticated products and the increased openness of countries to international trade stimulates internet usage. In addition, according to the relevant literature discussed in the introduction, countries that produce complex products are also wealthier, hence they tend to have more users accessing the world wide web, resulting in reverse causality issues. In order to estimate the causal effect, we follow a fixed effects two-stage least squares/instrumental variables (FE 2SLS/IV) strategy, using the two instruments for internet usage introduced in Section 3. We also include robust standard errors to correct for heteroscedasticity.

However, the joint significance of the two instruments seems to be weak in the first-stage statistics of the 2SLS/IV regressions, therefore our second strategy is to use the difference generalized method of moments (GMM) estimator (with robust standard errors) proposed by Arellano and Bond (1991), which is to time difference Eq. (1), to obtain[1]

$$\Delta \mathrm{ECI}_{\mathrm{i,t}} = \alpha \Delta \mathrm{ECI}_{\mathrm{i,t-1}} + \beta_1 \Delta internet_{i,t} + \beta_k \Delta controls_{i,t} + \Delta\delta_t + \Delta u_{i,t}. \quad (2)$$

where the fixed country effects are removed by time differencing. The GMM estimator is based upon the following orthogonality conditions: $E(ECI_{i,t-s} \Delta u_{i,t}) = 0$ for $t = 3, \ldots, T$ and $2 \leq s \leq T - 1$, where $ECI_{i,t-s}$ are suitable lags of the dependent variable. In essence, the second and further lags of the dependent variable are used as instruments in Eq. (2), in addition to the exogenous instruments listed in Section 3.

3. Data

Dataset 1: economic sophistication. We measure the economic sophistication of countries using the improved Economic Complexity Index (*ECI*). The *ECI* is estimated from data connecting countries to the products they export and measures the diversity and sophistication of a country's export structure, corrected for how difficult it is to export each product. It is freely available from MIT's Observatory of Economic Complexity (http://atlas.media.mit.edu). The index is calculated by applying the methodology described in Albeaik et al. (2017b). The *ECI* recognizes that institutions, knowledge and technology are prerequisites for economic growth, but in contrast to other indexes of growth, this index is measured with simple linear algebra techniques that determine the knowledge intensity of economies endogenously (from the data). Albeaik et al. (2017b) show that the improved economic complexity index outperforms the original economic complexity index (Hidalgo and Hausmann, 2009) in its ability to predict economic growth and in the consistency of its estimators across different econometric specifications. In a very recent working paper (Albeaik et al., 2017a) it is shown that the index is equivalent to the fitness complexity metric proposed by Tacchella et al. (2012).

Dataset 2: internet usage. The main variable of interest is the log of the *internet* users ratio: the number of people with access to the world wide network divided by the total population (individuals using the Internet as % of the population). The data were collected from the World Bank's World Development Indicators (WDI).

Dataset 3: instruments for internet usage. Applying a fixed effects 2SLS/IV regression in a dynamic panel-data setting requires a set of external instruments. While we do not have an ideal source of exogenous variation recognized by previous studies, there are two promising instruments of *internet* that we adopt in our analysis. We experiment with the two instruments described below and examine the robustness of our results by also using these instruments separately in our regressions.

Firstly, we employ the log number of secure *servers*, i.e., servers that use encryption technology in internet transactions (per 1 million people), from the WDI. We naturally expect secure internet *servers* to influence *internet* usage. In addition, it seems plausible to expect that changes in the number of *servers* have no direct effect on the sophistication of products exported by the countries.

For the second instrument, we follow Lin (2015) in considering the civil *liberty* index from Freedom House. The values of the index range from 1 to 7, with higher scores indicating fewer civil liberties. The underlying assumption for experimenting with this variable as an exogenous source of variation is that internet usage in a country depends on a government's attitude towards the free flow of ideas and civil rights. For example, China's world wide web includes neither Google, Facebook and YouTube nor the Economist, Time magazine and the New York Times. The 'Great Firewall of China' is a censorship system that controls online content and access to various information sources.[2] According to the latest Freedom House country report ('Freedom on the Net 2017') "*China was the world's worst abuser of internet freedom for the third consecutive year*". Syria, Cuba and Saudi Arabia are also ranked among the worst countries in the world for online freedom in the Freedom House's rankings.

[1] For a good textbook treatment of (dynamic) panel estimators see Baltagi (2008).

[2] 'The Great Firewall of China', Bloomberg News, December 1, 2017 https://www.bloomberg.com/quicktake/great-firewall-of-china.

Table 1
The effect of the Internet on economic sophistication.

	(1) Fixed effects 2SLS	(2) Fixed effects 2SLS	(3) Fixed effects 2SLS	(4) Fixed effects 2SLS	(5) Arellano-Bond GMM
ECI_{t-1}	0.772***	0.772***	0.752***	0.766***	0.312***
	(0.043)	(0.042)	(0.058)	(0.043)	(0.092)
internet	0.089**	0.090**	0.086**	0.085**	0.087**
	(0.036)	(0.037)	(0.040)	(0.040)	(0.042)
GDP per capita	0.019	0.094	0.390	0.346	−0.380
	(0.116)	(0.110)	(0.261)	(0.299)	(0.680)
pop dens	−0.053	0.333**	0.040	−0.068	−0.066
	(0.180)	(0.133)	(0.028)	(0.188)	(0.122)
education	−0.001	−0.001	−0.003	−0.000	0.014
	(0.001)	(0.001)	(0.002)	(0.001)	(0.017)
government				−0.001	−0.032**
				(0.003)	(0.014)
investment				−0.092	0.271
				(0.118)	(0.275)
inflation				0.010	0.135
				(0.051)	(0.134)
agriculture				0.060	−1.225
				(0.359)	(0.787)
First-stage results					
servers	0.207***	0.207***		0.187***	
	(0.052)	(0.053)		(0.052)	
liberty	−0.093**		−0.206***	−0.076*	
	(0.043)		(0.069)	(0.042)	
Observations	1064	1150	1720	1018	803
Countries	103	111	106	100	100
AR(1)					0.023
AR(2)					0.634
F-test	9.428	15.46	8.921	7.616	
DWH-test	9.716	9.011	8.741	7.946	
Weak-id	28.71	52.76	12.46	23.29	
LM-weakid	20.17	19.00	9.57	15.91	
Hansen (*p*-value)	0.365			0.343	

Note: Dependent variable: Economic Complexity Index (*ECI*); Main independent variable: log of individuals using the internet as % of the population. Columns (1)–(4): Fixed effects 2SLS/IV regressions with robust standard in parentheses (to save space, we only include the first-stage estimated coefficients of the instruments in the Table; results are available upon request). Column (5): GMM of Arellano and Bond (1991), with robust standard errors in parentheses. All regressions include year dummies. AR(1) and AR(2) are the p-values for first and second order autocorrelated disturbances. F-test gives the F-statistic for the joint significance of the instruments in the first stage. DWH-test is the Durbin–Wu–Hausmann test for the endogeneity of the regressors. Weak-id gives the Cragg–Donald F-statistic for weak identification. LM-weakid gives the Kleibergen–Paap Wald test of weak identification. Hansen (*p*-value) gives the *p*-value for the Hansen test of overidentification.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

Dataset 4: control variables. Based on previous literature, we include in the estimated equation a number of control variables that are likely to be related to economic sophistication. We mainly utilize a set of covariates based on the influential paper by Hausmann et al. (2007). The authors highlight the following crucial factors affecting economic sophistication: (a) the geographic potential of the country and the size of the labour force (represented by population density, *pop dens*, in our model; thousand people per sq. km of land area from the WDI), (b) the quality of the labour force i.e., human capital (represented by the number – in millions – of enrolled students in secondary *education*; from the WDI), (c) the country's level of development (represented by *GDP per capita*, PPP, constant 2011 international hundred thousand dollars; from the WDI). We verify the robustness of our results by adopting a set of additional controls drawn from the WDI: General *government* final consumption expenditures for purchases of goods and services to GDP ratio, gross domestic *investment* (gross capital formation) to GDP ratio, *inflation*, measured by the GDP deflator (annual change in percentage points), and the value added of *agriculture* to GDP ratio (to capture the structure of the economy).

4. Results

Table 1 lists the results when estimating Eq. (1) using fixed effects 2SLS/IV with the two exogenous sources of variation described above, year fixed effects and robust standard errors [columns (1)–(4)]; and difference GMM with year fixed effects and robust standard errors [column (5)].

According to the estimation results presented in Table 1, the effect of the Internet on economic sophistication is positive and statistically significant, as expected. This positive effect is robust to the inclusion of controls described in Section 3. The estimated coefficient of *government* is negative. The coefficients of the rest of the control variables are statistically insignificant.

In the fixed effects 2SLS/IV estimations we report: (a) the *F-test* for the joint significance of the instruments in the first stage: the rule of thumb is to exceed 10, hence the test implies weak significance (Stock and Yogo, 2005); (b) the Durbin–Wu–Hausmann (*DWH*) test for the endogeneity of regressors: the null hypothesis that the IV regression is not required is rejected; (c) the Cragg–Donald F-statistic (*Weak-id*) testing the relevance of the instruments in the first-stage regression: no evidence of instruments having a low correlation with the endogenous regressor after controlling for the exogenous regressors; (d) the Kleibergen–Paap Wald test (*LM-weakid*) of weak identification: the null hypothesis that the model is weakly identified is rejected; (e) the *p*-value for Hansen's test of overidentification: the acceptance of the null indicates that the overidentifying restrictions cannot be rejected. The values reported for AR(1) and AR(2) in the last column are the p-values for first and second order autocorrelated disturbances in the first-differenced equation. As expected, there is high first order autocorrelation and no evidence for significant second order autocorrelation. Hence, our test statistics hint at a proper specification.

5. Conclusion

This letter documents a positive effect of the Internet on economic sophistication (measured by the improved *ECI* available from MIT's Observatory of Economic Complexity). Our finding yields interesting policy implications, as it suggests that implementing policies that increase access to the Internet accelerates the productive capacity and the level of sophistication in an economy. Furthermore, by bringing together the two strands of literature on (a) the nexus between the Internet and economic development and (b) the nexus between economic complexity and economic development, this work links the methodology of economic complexity developed by physicists to the economics literature, showing that the direct positive effect of the Internet on economic growth (Choi and Yi, 2009) is accompanied by an indirect effect working through the improvement of product sophistication. In addition, it contributes one more determinant that can enhance the level of sophistication of an economy.

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References

Abdon, A., Felipe, J., 2011. The product space: What does it say about the opportunities for growth and structural transformation of Sub-Saharan Africa? Levy Economics Institte Working Paper (670).
Albeaik, S., Kaltenberg, M., Alsaleh, M., Hidalgo, C.A., 2017a. 729 new measures of economic complexity (Addendum to Improving the Economic Complexity Index). arXiv preprint arXiv:1708.04107.
Albeaik, S., Kaltenberg, M., Alsaleh, M., Hidalgo, C.A., 2017b. Measuring the Knowledge Intensity of Economies with an Improved Measure of Economic Complexity. arXiv preprint arXiv:1707.05826.
Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Rev. Econ. Stud. 58 (2), 277–297.
Baltagi, B., 2008. Econometric Analysis of Panel Data. John Wiley & Sons.
Blum, B.S., Goldfarb, A., 2006. Does the internet defy the law of gravity? J. Int. Econ. 70 (2), 384–405.
Bustos, S., Gomez, C., Hausmann, R., Hidalgo, C.A., 2012. The dynamics of nestedness predicts the evolution of industrial ecosystems. PLoS One 7 (11), e49393.
Caldarelli, G., Cristelli, M., Gabrielli, A., Pietronero, L., Scala, A., Tacchella, A., 2012. A network analysis of countries' export flows: firm grounds for the building blocks of the economy. PLoS One 7 (10), e47278.
Choi, C., 2003. Does the Internet stimulate inward foreign direct investment? J. Policy Model. 25 (4), 319–326.
Choi, C., 2010. The effect of the Internet on service trade. Econom. Lett. 109 (2), 102–104.
Choi, C., Yi, M.H., 2009. The effect of the internet on economic growth: Evidence from cross-country panel data. Econom. Lett. 105 (1), 39–41.
Clarke, G.R., Wallsten, S.J., 2006. Has the internet increased trade? Developed and developing country evidence. Econ. Inquiry 44 (3), 465–484.
Cristelli, M., Gabrielli, A., Tacchella, A., Caldarelli, G., Pietronero, L., 2013. Measuring the intangibles: A metrics for the economic complexity of countries and products. PLoS One 8 (8), e70726.
Cristelli, M., Tacchella, A., Pietronero, L., 2015. The heterogeneous dynamics of economic complexity. PLoS One 10 (2), e0117174.
Felipe, J., 2012. Inclusive Growth, Full Employment, and Structural Change: Implications and Policies for Developing Asia. Anthem Press.
Freund, C., Weinhold, D., 2002. The Internet and international trade in services. Amer. Econ. Rev. 92 (2), 236–240.
Freund, C.L., Weinhold, D., 2004. The effect of the Internet on international trade. J. Int. Econ. 62 (1), 171–189.
Gust, C., Marquez, J., 2004. International comparisons of productivity growth: the role of information technology and regulatory practices. Labour Econ. 11 (1), 33–58.
Hartmann, D., Guevara, M.R., Jara-Figueroa, C., Aristarán, M., Hidalgo, C.A., 2017. Linking economic complexity, institutions, and income inequality. World Dev. 93, 75–93.
Hausmann, R., Hidalgo, C.A., 2011. The network structure of economic output. J. Econ. Growth 16 (4), 309–342.
Hausmann, R., Hidalgo, C.A., Bustos, S., Coscia, M., Simoes, A., Yildirim, M.A., 2014. The Atlas of Economic Complexity: Mapping Paths to Prosperity. Mit Press.
Hausmann, R., Hwang, J., Rodrik, D., 2007. What you export matters. J. Econ. Growth 12 (1), 1–25.
Hidalgo, C.A., Hausmann, R., 2009. The building blocks of economic complexity. Proc. Natl. Acad. Sci. 106 (26), 10570–10575.
Hidalgo, C.A., Klinger, B., Barabási, A.-L., Hausmann, R., 2007. The product space conditions the development of nations. Science 317 (5837), 482–487.
Lapatinas, A., Litina, A., 2018. Intelligence and economic sophistication. Empir. Econom. (ISSN: 1435-8921). URL https://doi.org/10.1007/s00181-018-1511-y.
Lin, F., 2015. Estimating the effect of the Internet on international trade. J. Int. Trade Econ. Dev. 24 (3), 409–428.
Oliner, S.D., Sichel, D.E., 2000. The resurgence of growth in the late 1990s: is information technology the story? J. Econ. Perspect. 14 (4), 3–22.
Oliner, S.D., Sichel, D.E., Stiroh, K.J., 2007. Explaining a productive decade. Brook. Pap. Econ. Act. 2007 (1), 81–137.
Saviotti, P.P., Frenken, K., 2008. Export variety and the economic performance of countries. J. Evol. Econ. 18 (2), 201–218.
Sichel, D.E., 1999. Computers and aggregate economic growth: an update. Bus. Econ. 34 (2), 18–25.
Stock, J., Yogo, M., 2005. Testing for Weak Instruments in Linear IV Regression. Cambridge University Press, New York, pp. 80–108, URL http://www.economics.harvard.edu/faculty/stock/files/TestingWeakInstr_Stock%2BYogo.pdf.
Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A., Pietronero, L., 2012. A new metrics for countries' fitness and products' complexity. Sci. Rep. 2, 723.
Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A., Pietronero, L., 2013. Economic complexity: conceptual grounding of a new metrics for global competitiveness. J. Econom. Dynam. Control 37 (8), 1683–1691.
Vemuri, V.K., Siddiqi, S., 2009. Impact of commercialization of the internet on international trade: A panel study using the extended gravity model. Int. Trade J. 23 (4), 458–484.
Yi, M.H., Choi, C., 2005. The effect of the Internet on inflation: Panel data evidence. J. Policy Model. 27 (7), 885–889.