ECONOMIC COMPLEXITY AND TRADE: NEW EVIDENCES ON THE TECHNOLOGICAL GAP

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Abstract

Within modern evolutionary economics, the nexus of innovation and trade relationship is commonly regarded from a technological gap and gains of market-share for innovating countries. According to this strand, strongly related to the pioneer theorists of technological gap theory of trade, the technology-gap is the difference or technological distance between techniques employed by countries and those used by leading or innovative countries. However, measuring the technology-gap has been difficult, and proxies currently used – e.g. patents or R&D investments – are limited in many ways. This paper suggest that Economic Complexity Index (ECI) is an appropriate proxy for the countries' innovation performance and advances by creating a measure of technology-gap based in this index. Further, by means of a gravity equation I empirically estimated the technology-gap elasticity based on a panel of 90 countries covering the years from 1995-2012. Results indicate that the technological gap demonstrate important impacts on bilateral trade. The debate on technology and trade is central for economic development issues, especially for developing and underdeveloped countries.

Keywords: Bilateral Trade, Technology Gap, Gravity Equation, Evolutionary Economics.

JEL Codes: F12, F51, O33.

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1. Introduction

The idea of technical change positively impacting exports via improvements on production efficiency in innovating countries is broadly accepted, especially among theorists of the technological gap (Posner, 1961; Soete, 1981; Fagerberg, 1987; Maggi, 1993; Dosi et al., 2015; Verspagen, 1993) [1]. For these authors, technology gaps represents the level of advancement or efficiency of technologies adopted by countries – or firms within producing countries – compared to cutting-edge technologies available worldwide. Innovation can also simultaneously increase firm productivity and create a new product or a close substitute. This approach has emphasized technology differences between countries as the major driver of trade flows and patterns of specialization. Many times these differences are rationalized by ”product-cycle” hypothesis, as in the North-South models of trade – see Krugman (1979). Accordingly, technology evolution has distinct phases, from innovation to imitation, and capabilities of innovation is asymmetrically distributed across countries, as pointed out by Vernon (1966) and many others. Dosi et al. (2015), and Hufbauer (1970) formerly, advocate that trade flows are primarily driven from sector-specific absolute advantages, a result from strong asymmetries in countries capabilities to innovate and/or imitate. Importantly, advantages related to non-technological factors, such as land costs, human capital, among others, can potentially offset the benefits of technological leadership. Technology's diffusion pace and pattern are key to change impacts. In some cases elapsed time between an innovation and its critical adoption point can be delayed by the slow market acceptance of a new technology (Dosi et al., 1990, 2015; Dosi and Soete, 1988; Posner, 1961; Maggi, 1993).

Of course, technology differences across countries were considered a major source of Comparative Advantage (CA) also in the Ricardian model of trade. But, even in most modern version of Ricardian model, technology is usually regarded as unchangeable and fundamental for explaining specialization and trade gains. Besides, one can consider a related list of limitations including fully employment of all resources in every country, absence of dynamic increasing returns, perfect capital and labor mobility across sectors, among others. In other words, perfect competition, absence of trade barriers, homothetic preferences and, in some cases, geography, will necessarily create an world with certain degrees of specialization and trade of goods and services. Firms can differ in terms of technology, but perfect competition eliminates variety – see Dornbusch et al. (1977); Eaton and Kortum (2002) for a most recent formalization of Ricardian model.

Although the ”neotechnology hypothesis” has been accepted and empirically tested for several studies, economists have struggled with the lack of adequate proxies for the technology-gap, covering considerable set of countries. Currently, most

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[1] The technology-gap theories is also known as the ”neotechnology” hypothesis. This jargon was especially used by authors' during the 1980s.

studies rely on patent or R&D data, which is notably restrictive in terms of longitudinal extended availability, besides other flaws commonly related in terms of these proxies adequacy.

More recently, Hausmann et al. (2011) have proposed a innovative measure for *economic complexity* [2]. By economic complexity, the authors mean the amount of knowledge that a country has, expressed in the diversity and ubiquity of the products it makes (Hausmann et al., 2011). Noteworthy, author's description of knowledge, and how it is expressed in assymmetric innovative capacity around the globe, are notably analagous to ideas presented in many studies within evolutionary economics strand - see Dosi and Nelson (2010) for example. Moreover, the idea of differences in *economic complexity* as a source of notable asymmetries in the levels of economic development is consistent with both structuralist and evolutionary economics views of economic development challenges (Raúl, 1959; Prebisch, 1950; Gala et al., 2016; Fagerberg, 1987).

As ECI is build on the analysis of diversity and ubiquity of products supplied by a particular economy, it can be interpreted as a technology-output measure, likewise patents. Knowledge directly affects the capabilities of innovation and imitation, which is reflected at the complexity of the products a country produces. The ECI index is calculated from trade data and covers a large range of countries.

Besides, trade dispersion and attraction of bilateral trade have been treated by estimation of gravity equations in the field of empirical approaches to international trade for a long time – see Anderson and Wincoop (2003) for a generally accepted theory and estimation of gravity equation. However, only a few studies make use of these models to estimate technology elasticity of trade, based on the building blocks of technology-gap approach. Soete (1981), by considering variables such as GDPs and distance in her analysis of technology-gap impacts on trade, therefore, structured equations quite similar to modern specifications of gravity. As gravity equations are structured to analyze trade between trade partners, one can estimate the impact of the technology-gap between a pair of countries on their bilateral trade. Interesting, the bilateral approach open a room for a slight and equally important analysis of technology-gap. Pioneers theorists of the gap focused on a strictly multilateral approach, considering that leading countries trade more, no matter the destination of exports. Although this hypothesis is corroborated by several empirical studies, including this one, investigation of the role of the gap in bilateral trade is also of interest. I denominate this of bilateral technology-gap.

Thus, the aim of this paper is to estimate the impact of the bilateral technological gap on trade. In doing so, a gravity model extended by a bilateral technology-gap proxy based on ECI is estimated.

This study mainly contributes to the current literature by corroborating the ex-

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[2] Further information, datasets and publications are available at http://atlas.cid.harvard.edu

istence of effects of technical progress on trade. It advances by considering a new proxy for the technology-gap, more specifically a bilateral proxy based on ECI. A greater understanding of how technical progress and trade relates is paramount to economic development issues. This paper is divided into three remaining sections besides this introduction. Section 2 introduces the methodology. Section 3 presents the estimation results. Finally, section 4 concludes the paper.

2. Methodology

This is an empirical paper and a formal theory of technology-gap generating gravity is not fully delivered [3]. Major methodological challenge, at this point, is to structure a gravity equation extended by an adequate proxy for technology-gaps.

In doing so, I explicitly departed from most generally accepted specifications of gravity for panel data analysis – see Egger and Pfaffermayr (2003); Baltagi et al. (2014). Some of major concerns about misspecification of gravity equations amount to sample selection bias and estimation of linear models in the presence of heteroskedasticity. Also important, multilateral resistance to trade (MRT) and other non-observed countries' characteristics, and analysis of longitudinal data requires appropriate procedures to obtaining unbiased estimates. Taking this issues into account, country and year fixed effects were employed and a Poisson pseudo-maximum-likelihhod model was estimated in adittion to the usual Ordinary Least Square, as suggested by Silva and Tenreyro (2006) [4]. A model comprising such characteristics, i.e country and year fixed effects, are usually labeled as a three way model. The final equation to be estimated can be written as follows, in its linear form:

$$m_{ijt} = \beta_0 + \varphi y_{it} + \alpha y_{jt} + \gamma_{ij} + \omega_j + \lambda_j + \delta_t + \sigma T_{ij} + u_{ijt} \tag{1}$$

where, lower case represents the logarithm of corresponding variables, and y_{it} is the country i's income, y_{jt} country j's income, γ_{ij} is a vector of time-invariant bilateral costs, commonly proxied by geographic distances and a set of dummies identifying colonial ties, common language, contiguity, among others. ω_j, λ_j and $delta_t$ are, respectively, fixed effects for country j, country i and time. Finally, $sigmaT_{ij}$ is the technology gap between country i and country j. Note that $sigmaT_{ij}$ is not linearized in the final equation. Estimates were also performed with the natural logarithm of $sigmaT_{ij}$, returning similar results in terms of statistic significance and signals. However, R^2 for both models revealed that the variable is preferred in its non linearized form. Fixed effect interaction between countries and time are

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[3] Theory has been developed and will be published in the future.

[4] Two-stage estimations *a la* Heckman are broadly employed by trade economists, especially in the presence of strong evidences of sample selection. Helpman et al. (2008) developed a complete framework for a two-stage analysis, which treats for sample selection and firm heterogeneity.

not included, although recommended by part of the literature, but incomes of country i and j have been considered a satisfacotry control for such effects Egger and Pfaffermayr (2003). Also, interactions between countries and year would turn the estimation of bilateral-gap elasticity inappropriate based on theory considered. If changes in countries relative position regarding technology is considered, at best, rare, the bilateral-gap is almost time invariant. All tests and models were run in the Comprehensive R Archive Network (R Cran) making use of several packages, including *gravity*, *plm*, *glm*, *sandwich*, *lmtest*, *car* and *tseries* packages.

2.1. Data

Data on bilateral trade derives from the BACI database, which was developed by CEPII at a high level of product disaggregation (for detailed information see Guillaume and Zignago (2010)). Data was aggregated to obtain country's total trade value by partner and year. General gravity data, such as distance, colonial ties, common language, contiguous, among others, come from the GeoDist database also by CEPII (for detailed information see Mayer and Zignago (2011)). Gross Domestic Product at current prices comes from the IMF database. Finally, ECI were obtained directly from the data set made available by The Atlas of Economic Complexity team.

Final database comprises 145,440 observations for 18 years, 36 variables, and 90 different countries. From this sample, 130,662 observations returned positive trade flows. In Box 2, in Appendix A, we briefly describe all (7) variables that actually entered the final estimations.

2.2. Bilateral technology-gap proxy

This paper sample considered, ECI index varies from -2.20800 to 3.25200. Looking to create a measure of bilateral technology-gap, one could simply create any relation between partners to capture their differences in terms of innovative performance. Let T_{it} be the technology status in country i in year t and T_{jt} the same for country j. Thus, T_{it}/T_{jt} is the ratio of country i' technology in relation to technology in country j. If ECI was strictly positive, one could assume $ECI = T_{ij}$, thus $T_{ij} > 1$ would signify country i has superior innovative capacity when compared to country j, and, analogously, $T_{ij} < 1$ would return the opposite statement. However, ECI is not strictly positive. Thus, it was needed to re-scale ECI to comprise strictly positive values ranging from 1 to 6.460. It was carried out by simply summing up a constant of value 3.20800 to all values within the time series [5].

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[5] Another way to calculate technology gap is to simply subtract original ECI of country i from ECI index of country j. Estimations were also employed to this alternative measure, but model significance is better when the ratio of re-scaled ECI is considered. Nonetheless, both measures of bilateral technology-gap returned positive and significant values for all models.

3. Results and Discussion

Results are presented in Table1. As above mentioned, although being the most common econometric procedure, estimation via OLS may return biased coefficients in presence of heteroskedasticity, and it requires the drop out of non-positive trade volumes. Poisson pseudo-maximum-likelihood (PPML), however, is robust in presence of heteroskesdasticity and can be estimated over the entire sample regardless positive and non-positive trade links. As there is no consensus about the best procedure to gravity estimation, results from both models are presented to reinforce robustness. Remarkably, results are consistent within and between both models.

Table 1. Estimates Results – Dependent Variable Bilateral Trade

	OLS (1)	*PPML* (2)
Distance	-1.451 ***	-0.911 ***
	(0.008)	(0.012)
Income $_i$	0.553 ***	0.796 ***
	(0.029)	(0.055)
Income $_j$	0.757 ***	0.937 ***
	(0.028)	(0.048)
Colony	1.064 ***	0.356 ***
	(0.023)	(0.026)
Language (ethno)	0.684 ***	0.065 **
	(0.017)	(0.021)
Land Border	0.460 ***	0.363 ***
	(0.033)	(0.022)
Tech Gap	0.302 ***	0.120 **
	(0.021)	(0.046)
(Intercept)	-17.416 ***	-27.650 ***
	(0.932)	(1.434)
Observations	130,662	145,440
R^2	0.8034	
Adjusted R^2	0.8031	
Resid. Std. Error	1.579 (df=130459)	
F Statistic	2797***	
	(df = 202; 130459)	

Note: * p<0.05; ** p<0.01; *** p<0.001
Robust Standard Errors for both models.
Year and country fixed effects omitted.

Time-invariant bilateral effects γ_{ij} - distance, colonial ties, common language and contiguity - returned expected coefficeint values in terms of signal and magnitude based on literature and trade theory. Distance are expected to increase bilateral trade costs, as stated by the hypothesis of iceberg costs (Samuelson, 1952). Cultural ties measured by colony and language are expected to increase bilateral trade, as well as the existence of a land border. Noteworthy, as reported in the seminal paper by Silva and Tenreyro (2006), colony and common language returns considerable smaller coefficients when PPML estimation is performed.

Let us focus on the estimated technology-gap elasticity obtained from both models. It is statistically and economically significant in both models, confirming the impact of bilateral technology-gap on trade. Importantly, estimates for the same sample reveals that countries with higher ECI indexes, without any transformation, exports significantly more no matter the destination – 0.232 with $p < 0.0001$ in the PPML model, which consistently returns smaller coefficients values for all estimates. It corroborates the importance of technology-gaps to trade and suggests that multilateral gap is more important than bilateral gap in determining trade – coefficient value 0.120 in PPML. However, the bilateral gap is also important and brings out different information on bilateral trade formation. In words, a positive impact of bilateral-gap on trade means that bilateral trade volume is greater when exporter has greater innovative capacity in relation to importing country. It reveals the asymmetric nature of trade in presence of technology-gaps and reinforces trade links based on North-South dynamic. That is, results suggest a natural trend in formation of asymmetrical commercial relations, between advanced and non-advanced economies, based on technology capacities. Moreover, the ”North” - or simply most innovative countries - relies on its innovative capacity to keep their commercial advantages. As innovative capabilities is asymmetrically around the globe, and they impact trade significantly, world trade network is not expected to change drastically over time. This ”stability”of world trade network is corroborated by empirical works Fagiolo (2009). Papers results combined with other pieces of work reinforces the hypothesis that imitation is becoming costly, given the complexity of modern technologies which requires articulation of a vast ”pieces” of knowledge. As imitation is the counter-force closing the gaps, one can expected increases in technology gap in the future.

4. Conclusions

In this paper, I evaluated the impacts of technological gap on bilateral trade through a proxy based on the Economic Complexity Index (ECI). Using such a proxy and treating the technology-gap from the bilateral perspective are two of the major contributions of this paper. The model considers that bilateral trade is a function of sizes, trade variable and fixed costs, and technology gap. It is an extension of traditional gravity equations. Results show that bilateral technology gap significantly impact bilateral trade, and corroborates the importance of multilateral gap. Our findings may contribute to improved policy design, showing, above all, the importance of industrial policies focused on innovation or imitation capacity to close bilateral and multilateral gaps. Finally, given industry specialization, bilateral gap is expected to impact in greater magnitude bilateral trade, when sector trade is considered. Future research on sector data can reveal interesting results about bilateral-gap and trade dynamics.

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A Appendix A

Table 2. Variables Description

Variable Name	**Description**	**Source**
Bilateral Trade	USD value of annual exports by year and partner - original variable v.	BACI-CEPII
Income $_i$ and Income $_j$	Gross Domestic GDP in current dollars - original variable Y_USD_crt.	IMF
Distance	Geodesic distances between most populated cities.Distance (or $distw$ in original database) was calculated following the great circle formula.	GeoDist -CEPII
Land Border	Dummy variable assuming value 1 if i and j are contiguous, 0 otherwise.	GeoDist -CEPII
Language (ethno)	Dummy variable assuming value 1 if i and j share a common language spoken at least by 20% of the population, 0 otherwise.	GeoDist -CEPII
Colony	Dummy variable assuming value 1 if i and j had/have a colonial tie, 0 otherwise.	GeoDist -CEPII
Tech. Gap	Ratio of re-scaled ECI index of country $_i$ over re-scaled ECI index of country $_j$	Atlas of Eco. Complexity

Table 3. Descriptive statistics

Statistic	N	Mean	St. Dev.	Min	Max
Distance	145,440	7,420.5	4,469.2	114.6	19,539.5
Income $_i$	145,440	467,522,145,902.0	1,396,413,284,828.0	1,370,000,000	13,600,000,000,000
Income $_j$	145,440	467,522,145,902.0	1,396,413,284,828.0	1,370,000,000	13,600,000,000,000
Tech. Gap $_ij$	145,440	1.1	0.6	0.2	6.4
Colony	145,440	0.03	0.2	0	1
Language (ethno)	145,440	0.1	0.3	0	1
Land Border	145,440	0.03	0.2	0	1