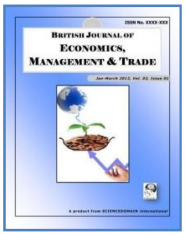

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On the Effect of Technological Gap on International Patenting: A Multi-Criteria Approach

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

This paper tests the effect of technological distance (the difference in technological progress between two countries) on the bilateral technology diffusion, measured by the flow of patent applications. To do so, the PROMETHEE II method is applied in order to construct an annual technological ranking of 18 OECD countries based on a number of technology variables. Then, the normalized estimated scores are used to show empirically that the effect of technological distance on technology diffusion cannot be unambiguously determined and it depends on whether the source country is a low or a high ranking country. High ranking countries export patent applications to high ranking countries, unlike low ranking countries which do not seem to follow this pattern.

Keywords: Technological gap; patents; PROMETHEE II.

1. INTRODUCTION

The literature supports the hypothesis that technology diffusion is more intense between countries with small technological gap [1] where technological gap is defined as the difference in the technological progress between the two parties. A major channel of technology or

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innovation diffusion is through the export of patent applications from one country to another, that is, international patenting [2]. Inspired by the Newton's law of gravitation, international flows (either trade or patent flows) are often modeled by means of gravity models where it is assumed that the bilateral flows are related to specific features of both the importer and the exporter as well as some other gravity variables such as the geographical distance between the two parties [3,4]. Regarding international patent flows, [5] show that a significant factor that determines US patent exports is the technological progress of the destination country measured by the total number of patent applications yearly.

This paper follows a different approach to test the significance of technological distance to international patenting. A complete annual technological ranking of 18 OECD countries for the period 2000-2011 is created by applying one of the most reliable outranking multi-criteria approaches, the PROMETHEE II methodology (Preference Ranking Organisation Method for Enrichment Evaluations). The ranking is based on three criteria: The number of patent applications, the R&D investments and the Venture Capital investments. Based on those rankings the hypothesis that international patenting occurs between countries that are close in the ranking (i.e. facing a small technological gap) is challenged by providing evidence that this holds only for source countries that rank high. It is shown that countries with low technological advancement (low ranking countries) do not show any preference in exporting patents towards countries that are technologically closer or higher compared to them but they base their decisions on other factors such as the geographical proximity and the property rights protection regime.

The paper is structured in the following way: First, the dataset is presented, then the PROMETHEE II method and finally, the statistical methodology and results. The paper ends with a concluding section.

2. DATA

The data are annual, covering the period 2000-2011 for the following 18 OECD countries: Austria, Belgium, Canada, Czech Republic, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Netherlands, Poland, Portugal, Spain, Sweden, UK and USA. In total, 216 observations are employed, structured as a panel. All data were retrieved from Eurostat's and OECD's databases except for the Intellectual Property rights Index (IPR) which is published online by the "Property Rights Alliance" and the patent data which were retrieved from the World Intellectual Property Rights Organization (WIPO). Table 1 presents some statistics of the sample regarding the number of patent applications, the R&D and Venture Capital investments and the IPR index.

3. MEASURING TECHNOLOGICAL PROGRESS WITH PROMETHEE II

To assess a country's technological progress, three variables are taken into consideration: a) The total number of patent applications (*P*) b) the R&D investments and c) The Venture Capital (*VC*) investments. The first two are traditionally considered as measures of technological advancement. *VC* is included for the reason that it is a type of investment directed to small innovative firms and it thus provides patentees with a channel to commercialize their inventions [6,7]. Using these three variables the paper ranks 18 OECD countries using the PROMETHEE II methodology. PROMETHEE II was introduced by [8] and provides a full ranking of all countries by weighting the chosen criteria. Choosing the proper weights might be a drawback of this approach. This paper uses a common method of calculating weights, the Rank Order Cendroid (ROC). Each criterion's weight is calculated with the following formula

$$w_i = \left(\frac{1}{M}\right)\sum_{i=1}^{M}\left(\frac{1}{r_i}\right) \quad (1)$$

Where r_i is the rank of criterion $i \in \{1,...,\mathrm{M}\}$. The three criteria are ranked in the following order: 1) P, 2) R&D and 3) VC. The reason R&D is ranked lower than patent applications is that the outcome of R&D investments is ambiguous unlike patent applications that have already gone through an R&D process. On that basis, the weights given by the ROC method for *P*, *R&D* and *VC* are 0,61, 0,27 and 0,11 respectively. For every criterion value c_i^k, where superscript *k* denotes country *k* and $k \in \{1,...,\mathrm{K}\}$, PROMETHEE II makes all possible pairwise comparisons $d_i^{k,l} = c_i^k - c_i^l$ between all countries. Then, a preference function is associated with each criterion in the following way

$$PR(d_i^{k,l}) = \begin{cases} 1, \text{ if } d_i^{k,l} > 0 \\ 0, \text{ if } d_i^{k,l} < 0 \end{cases} \quad (2)$$

which transforms the difference $d_i^{k,l}$ into a preference degree. The above preference function is chosen due to its simplicity and in order to avoid extra assumptions about thresholds determining the preferences. All preference degrees are then weighted as follows

$$\Pi^{k,l} = \sum_{i=1}^{M} PR(d_i^{k,l}) w_i \quad (3)$$

Finally, country *k* receives a score according to the following function

$$FL_k = \frac{1}{n-1}\left(\sum_{l=1}^{K} \Pi^{k,l} - \sum_{l=`1}^{K} \Pi^{l,k} \right) \quad (4)$$

which is usually called the *net outranking flow* (henceforth *FL*). Specifically, *FL* is a measure of how much each country outranks - and is outranked by - the alternative countries and consequently, countries are ranked according to their *FL* score. As a measure of technological progress this paper uses a normalized *FL* variable so that the highest ranking country will have a score of one.

PROMETHEE II rankings reveal that USA has constantly the highest *FL* score for the given period. On the other hand, certain 5 countries (Belgium, Czech Republic, Hungary, Ireland, Portugal) are interchangeably at the lowest 5 positions. Some results of PROMETHEE II are presented in the Appendix.

4. RESULTS

The target is to test the following Hypothesis:

Hypothesis 1: *The smaller the technological gap between two countries, the higher the patent application exports.*

Specifically, a relation of the following form will be estimated

$$PATENT\ EXPORTS_{s,i,t} = F(FL_{i,t}, DISTANCE_{s,i}, GROWTH_{i,t}, IPR_{i,t}) \quad (5)$$

where $PATENT\ EXPORTS_{s,i,t}$ is the export of patent applications from the source country *s* to the destination country *i* at year *t*, *FL* is the score calculated by PROMETHEE II, *DISTANCE* is the geographical distance between the target and the source country[1], "*IPR*" is the Intellectual Property Rights protection index of the target country and "*GROWTH*" is the target's real GDP growth. The *FL* variable of PROMETHEE II has been normalized so that the highest ranking country will always have a score of one for every year of the dataset.

Table 1. Technology variables (average values over 2000-2011)

Country	Patent applications	R&D (%GDP)	Venture capital (%GDP)	2011 IPR index
Austria	2468.25	2.41%	0.04%	7.9
Belgium	723.6667	1.94%	0.07%	7.5
Canada	38890.92	1.97%	0.25%	8
Czech republic	2187.5	1.37%	0.03%	6.5
Finland	2159.75	3.55%	0.10%	8.5
France	16882	2.18%	0.08%	7.3
Germany	60083.92	2.60%	0.06%	7.8
Hungary	2469	1.00%	0.04%	6.4
Ireland	921.6667	1.34%	0.07%	7.6
Israel	6935.833	4.48%	0.83%	6.3
Italy	9656.417	1.15%	0.04%	6
Netherlands	2759.5	1.89%	0.11%	8
Poland	5003.167	0.62%	0.03%	6.2
Portugal	313.25	1.07%	0.06%	6.9
Spain	3424.25	1.16%	0.08%	6.5
Sweden	3301.583	3.62%	0.18%	8.5
Uk	27225.08	1.77%	0.19%	7.7
Usa	412671.6	2.71%	0.20%	7.5

[1] *Geographical distance was retrieved from www.cepii.fr and is calculated by properly weighting the bilateral physical distances between the principal cities of two countries*

Because patents are positive integers, proper count panel data techniques have to be used. The most popular is the Negative Binomial regression whose advantage over its Poisson counterpart is that it allows for possible overdispersion[2]. Two models are estimated. In the first model, the dependent variable is USA's annual export of patents to each of the dataset's countries. USA is chosen because it is the country that is constantly in the first position in the PROMETHEE II rankings. In the second model, the dependent variable is the annual sum of patent exports of Belgium, Czech Republic, Hungary, Ireland and Portugal which are the countries that constantly rank at the five lowest positions. In the second model it is difficult to define geographical distance between multiple source countries and each target country. Instead, a dummy is used which takes the value 1 whenever the target country is European (as all the five source countries). The Lagrange multiplier test indicates that random effects are present in both models[3]. The results are summarized in Tables 2 and 3.

In Table 2 the dependent variable is the US patent exports. The variable *FL* is significant implying that US patents are directed towards countries that are high in the ranking. Therefore, the narrower the technological gap, the higher the exporting of patents which partly verifies Hypothesis 1. GDP growth, *Distance* and the *IPR* index are also significant and positive. The positive sign of *Distance* might seem puzzling at first. Note that distance is basically a measure of transportation costs. Many of the Patent Offices worldwide accept online submissions of patent applications and thus, the cost of distance should be minimized. Moreover, it is possible that a great part of the innovative activity in the US is undertaken by multinational enterprises with a global perspective aiming to protect their inventions worldwide.

In Table 3 the dependent variable is the annual sum of patent exports of the five lowest ranking countries. The variable FL is insignificant implying that technological gap is not a significant factor of international patenting for the specific model. On the other hand, *GROWTH, EU DUMMY* and the *IPR* index are statistically significant and positive.

Table 2. Dependent variable: USA patent exports

Variables	Coef
Fl	0.754*
	(0.267)
Growth	5.569*
	(1.564)
Distance	$0.1x10^{-3}$**
	($0.7 x10^{-4}$)
Ipr	0.346**
	(0.161)

*Std errors in parenthesis, *1% significance, **5% significance*

Table 3. Dependent variable: patent exports of Belgium, Czech Republic, Hungary, Ireland, Portugal

Variables	Coef
Fl	0.107
	(0.401)
Growth	4.699**
	(2.250)
Eu dummy	1.609*
	(0.460)
Ipr	1.066*
	(0.291)

*Std errors in parenthesis,*1% significance, **5% significance*

4. CONCLUSION

This paper evaluated the importance of technological gap between the source and destination country on the technology diffusion between them. Technology diffusion was measured by the size of patent application exports. In order to have a measure of technological gap the paper constructed a yearly ranking of 18 OECD countries for 2000-2011 using the PROMETHEE II outranking method. The ranking was based on three criteria, namely the number of Patent applications, the R&D and Venture capital investments. Then, two Negative Binomial models were estimated where the dependent variables were the annual export of patent applications of the USA (the constantly highest ranking country) and the annual export of patent applications of the five lowest ranking countries respectively. The PROMETHEE II scores of the destination country were included among the regressors as a measure of its technological progress. It was shown that technological gap is a significant factor of international patenting only for high ranking countries. On the other hand, low ranking

[2]*The variance is difference than the mean*

[3]*For the first model χ^2=108.1 and for the second model χ^2=601.88. Both statistics reject the null hypothesis that random effects are not present at 0,01 significance level*

countries base their decisions on geographical proximity, strength of intellectual rights protection and destination economy's growth.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

PROMETHEE II results for 2008-2011 (before normalization)

2008			2009		
Rank	**Countries**	**Flow**	**Rank**	**Countries**	**Flow**
1	USA	0,8884	1	Usa	0,8884
2	Germany	0,6673	2	Germany	0,6673
3	Israel	0,5691	3	Israel	0,5691
4	Canada	0,5544	4	Canada	0,5673
5	France	0,4377	5	Uk	0,4238
6	Uk	0,4367	6	France	0,4119
7	Sweden	0,3338	7	Sweden	0,1773
8	Finland	0,0407	8	Finland	0,0536
9	Italy	-0,0724	9	Italy	-0,0465
10	Spain	-0,0797	10	Netherlands	-0,0917
11	Austria	-0,1355	11	Austria	-0,0967
12	Netherlands	-0,1442	12	Spain	-0,1443
13	Poland	-0,3996	13	Poland	-0,3537
14	Ireland	-0,4254	14	Ireland	-0,3731
15	Belgium	-0,5345	15	Belgium	-0,3981
16	Czech republic	-0,6012	16	Czech Republic	-0,5948
17	Portugal	-0,725	17	Portugal	-0,7773
18	Hungary	-0,8105	18	Hungary	-0,8824

2010			2011		
Rank	**Countries**	**Flow**	**Rank**	**Countries**	**Flow**
1	USA	0,8884	1	Usa	0,8555
2	Germany	0,6802	2	Germany	0,6937
3	Israel	0,5691	3	Israel	0,5691
4	Canada	0,5379	4	Canada	0,4357
5	France	0,4377	5	France	0,4119
6	Uk	0,3909	6	Uk	0,4038
7	Sweden	0,1184	7	Sweden	0,1054
8	Finland	0,0536	8	Finland	0,0407
9	Netherlands	-0,0553	9	Austria	0,001
10	Austria	-0,0572	10	Netherlands	-0,0453
11	Italy	-0,0595	11	Italy	-0,0724
12	Spain	-0,1573	12	Spain	-0,2032
13	Poland	-0,3537	13	Poland	-0,256
14	Belgium	-0,4498	14	Belgium	-0,3909
15	Ireland	-0,4708	15	Czech Republic	-0,4236
16	Czech republic	-0,5359	16	Ireland	-0,6733
17	Portugal	-0,7062	17	Hungary	-0,6813
18	Hungary	-0,8306	18	Portugal	-0,7707

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