

Global and domestic centrality in patent citation networks

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When a national government invests in industry, the goal is to promote spillovers[1], or information flow between classes[2], *within the domestic economy* rather than worldwide. In a competitive global economy, the optimal national investment strategy may therefore not be reflected in the rankings of well known measures of network centrality in many contexts[3, 4, 5] because they do not take political borders into account (schematically diagrammed in Fig. 1). It is important in many contexts to quantitatively determine high-impact, central patent classes that are likely to provide domestic spillovers of information, with the patent citation network acting as a useful dataset with which we can work.

Newly issued patents may be cited by a diverse set of other patent classes at any time in the future, making an analysis of the effect of a stimulus difficult. By assuming that the information generated by government funding predominantly benefits a single class relatively recently, it is possible to describe the motion of the original information moving about the patent citation network as a random walk. Such a walk allows us to determine a measure of centrality of each patent class equivalent to the PageRank centrality[4]: the steady state probability that the information will be found at that class. We introduce an additional bias against the information crossing a political border (as depicted in Fig. 1) quantified by the free parameter $0 \leq \epsilon \leq 1$, where there is no consequence of border crossing at $\epsilon = 0$ and where information is effectively destroyed by border crossings at $\epsilon = 1$. This free parameter allows us to continuously tune between a global (with $\epsilon = 0$) and domestic (with $\epsilon = 1$) measure of centrality, determining the patent classes that are of primary domestic benefit to each individual country.

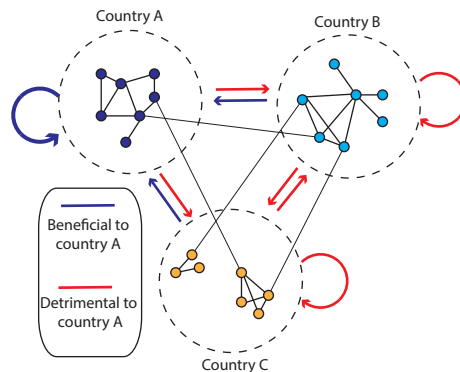


Figure 1: A schematic of the citation network of patent classes for each country, with classes denoted by nodes and citations denoted by thin edges. Information flow that benefits foreign classes is expected to be detrimental to the domestic economy, indicated by the red arrows. If a country were to create information from directly funding a domestic class that exclusively caused foreign spillovers, the stimulus would be subsidizing a foreign economy. In our model, information moving in the direction of the blue or red arrows is considered ‘beneficial’ or ‘detrimental’, respectively.

In Fig. 2, we show the behavior of the centrality for the top five globally central classes for the US, Japan, and Germany in 1995 as ϵ is varied. In all cases we see an overall decrease in the measured centrality, which is due to the increase teleportation probability at every step of the random walk as ϵ increases. The *relative* decline when comparing two central classes is due entirely to the topology of the citation network and is a signal of the difference between

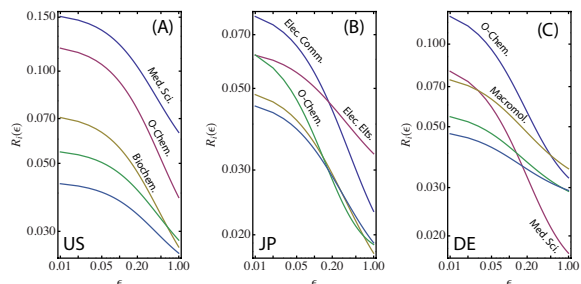


Figure 2: Shown is the behavior of centrality as a function of the asymmetry parameter ϵ for the three largest countries in 1995 (plotted on log-log axes). The centrality of each class ϵ is varied depends on the country: in (A), there is only one permutation in the US's top five list, with minor differences between classes in the computed centralities as ϵ increases, while there is a drastic reduction in Japan (B) and Germany's (C) second-highest globally ranked class of Organic Chemistry and Medical Science, respectively.

global and domestic centrality. In some cases, in particular the US, high ranked classes are robust to variations in ϵ over a fairly wide range (up to $\epsilon \sim 0.1$ compared to the more rapid drops observed for other countries) and the ordering of the top-five classes is unchanged over nearly the entire range of values of ϵ . This is due to the overall centrality of the US economy: since the most patents are issued to the US a larger share of citations are domestic. Conversely, the Japanese and German economies show a greater degree of rearrangement, with the most central class globally *not* the most central domestically. This effect is most pronounced in Japan's Organic Chemistry patents and Germany's Medical Science patents (both dropping from #2 to #5 or lower). The significant changes in the centralities for these countries indicate that national investment strategies may benefit by considering not

only the global network topology using standard measures of centrality, but also by incorporating the domestically-centered measure of centrality presented here.

- [1] B. Gress. *World Patent Info.*, 32:3, 2010.
- [2] D. T. Coe and E. Helpman. *Eur. Econ. Rev.*, 39:859, 1995.
- [3] S. Boccaletti et. al. *Phys. Rep.*, 424:175, 2006.
- [4] M. Franceschet. *Com. ACM*, 54:92, 2011.
- [5] M. E. J. Newman. *Soc. Net.*, 27:39, 2005.

About Our Group: The AXES lab at IMT Lucca brings the expertise of Economists, Statisticians, and Network Scientists together to study a broad range of topics, leveraging our diverse backgrounds to better understanding complex problems. A few active projects includes this work (studying the information flow between patent classes), the structure and evolution of interdependencies between patent classes, or the interplay between geographical and technological distance in the structure of the citation network.