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Reinhilde Veugelers (Université Catholique de Louvain), Belgique

"China and the USA: a G2 for Science?"

TRANSCRIPTION

Nous sommes heureux d'avoir Reinhilde Veugelers. Je viens de faire les statistiques : sur quatre séances, on a eu trois femmes, donc on est à peu près dans la parité. On essaiera d'avoir quelques hommes dans le futur, surtout que la prochaine est aussi avec une femme... C'est peut-être significatif.

Reinhilde est professeur de management, d'économie et de stratégie sur l'innovation à l'université catholique de Louvain. Elle est partout. Je l'ai personnellement rencontrée à peu près dans une quinzaine de pays, dans tous les pays européens, mais aussi en Turquie, en Chine et aux États-Unis. Je me rappelle très bien que nous nous sommes rencontrés aussi bien dans ces pays qu'en Belgique et en France.

J'ai essayé de me documenter hier sur ce qu'elle publiait, puisque je connais certains de ses papiers, et j'ai consulté IDEAS, c'est un système pour la France qui recense les publications de presque 20 000 économistes, une base mondiale. Je vois cinq pages, j'imprime, et à ma stupeur j'ai eu 30 pages, donc je n'ai pas eu le temps de tout voir ; néanmoins, ce document nous dit des choses très intéressantes. Il nous donne notamment vingt indicateurs – je ne vais pas tous les signaler –, et il se trouve que pour ces vingt indicateurs, qui vont de l'*average rank score* au *H index*, elle est à chaque fois dans les 5% de premiers. C'est un bon indicateur de sa notoriété.

D'autre part, les deux articles qui sont les plus cités sont d'abord celui sur la coopération en recherche et développement et les externalités, pour la Belgique, papier écrit avec Bruno Cassiman qui a eu énormément de succès, et dont beaucoup de chercheurs se sont inspiré pour réaliser des études comparables dans d'autres pays. Et récemment, celui qui est le plus cité dans les 12 derniers mois, concerne un thème important : comment financer les PME en Europe.

Aujourd'hui elle va nous présenter un papier qui s'intitule : « Va-t-on vers un G2 en sciences ? » Ce G2 étant constitué, évidemment, des États-Unis et de la Chine.

Je laisse la parole à Reinhilde Veugelers pour une heure.

Reinhilde Veugelers :

I have to apologize not to be able to do this in French, my French is not good enough, but I'm very happy to take questions in French.
Thanks for the invitation; we are very happy to be able to present this teamwork about globalization in sciences. From an economical and general perspective, I think this is a very important phenomenon that deserves an invitation here. Other topics interest me, like the financing of young companies, but that will be for another time.

So, my main purpose here is that we are evolving towards a global science world, and the only question is how many poles there will actually be…

What I would like to do during this talk is to show you lots of data, so you can decide by yourself what is going on. I'll show you data on the shifts in where science is actually being produced, which are showing the emergence of new scientific powerhouses, but then we will also be looking at the impacts of these shifts in the locations where science is being produced. First, mainly, what the impact will be on the science process itself; how it would affect the mobility of researchers, which is a very important component of how science is being produced; how it will affect the collaboration between scientists.

And then, there is also an impact of growth beyond science: how does that affect research innovation, and ultimately also growth and competitiveness.
I would like to underline some policy implications, particularly policy implications for Europe.

First of all, this question of the globalization of science is not so unexpected here… It's part of the overall process of globalization of the economy.

It is also firms that tend to be more active internationally, not only in the production of sales, but also in their R&D activities, which are being done increasingly globally. This open perspective also means that firms are much, much more looking for external scientific sources on a global scale, which also drives globalization of science.

Another important element is that scientific talents, students as well as scholars, are increasingly mobile. It's easier for people to move globally. The cost of international scientific activity – when we organize and produce science internationally in cooperation – has also been drastically reduced, with the help of ICT and Internet, which boosted non-physical exchanges in scientific work, that come on top of the physical exchanges.

There is another factor that may drive this globalization of science, such as the policy attention. Increasing a policy stating that it is important to improve the collecting of science research and spending efforts on stimulating the internationalization of higher education in science is triggering a switch.

Particularly in Europe we have improving data, certainly thanks to the European projects ERA and EHA, in the higher education area, that stimulate, at least within the European framework, this internationalization of science.

So, with all these trends, it is not so surprising that we have a globalization of science, but there are also counterforces; it's not that straightforward a process.

One important opposing force is still the national dimension of many science education and technology (EST) policies here, that still focus a lot on how to improve the national systems and therefore of course also make sure that the attention of researchers is more driven to national policies rather than to international policies, and that they will collaborate more with other national scientists.

Another important opposing force that impedes the globalization of science is that despite the reduced cost for international collaboration, we lack effective exchange and proximity. We need to be able to talk on a very informal basis, regularly, whenever we need, during coffee breaks; proximity stimulates creativity and new ideas, so it is a very important component for productive exchanges.

Amongst the opposing forces, there is also the inertia of networks that have been formed for a long time. People tend to stick to these networks, collaborating with people that they know. These networks only change very gradually over time. They don't necessarily follow the shifts in where new science is produced.

Overall, the tendency of the globalization of science is not a big revolutionary shift; it definitely is a process that proceeds gradually.

Let's have a look at the data showing how the internationalization of science is evolving. First of all, we are going to see where science is actually produced (we look at scientific working papers, scientific publications, etc.).

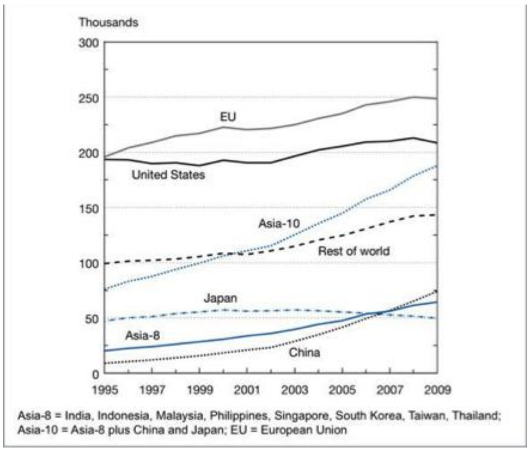
The feature I would like to show is the spectacular rise of China.
Since 2004, it has dramatically increased its scientific output, surpassing many of the strongholds such as Japan, the U.K., and Germany in 2006. It is now only standing second to the U.S., and is heading to overtake them in output within the next decade.

If you're looking at the trends, China's rise is very spectacular, but it's not the only example of non-Triad rise. Other countries are also rising in an upright pattern, countries that are sufficiently large and also very dynamic, such as South Korea, Brazil and Turkey. It's not actually a BRICs story in terms of science output, because if you take a look at India and Russia, these countries are not strong advisers on science.

This rise of other poles is not necessarily a story of old poles declining. We still see an absolute growth of U.S. and E.U. scientific publications, so science is not a zero-sub game, it's something that seems positive for the overall scientific output and production. Nevertheless, if you take a look at the data for the last two years, you see that absolute numbers from the US and the relative share of the EU has started to edge downward.

I also want to show it's not only a matter of number of publications, but there is also a definite catching up in quality, although much less impressive than the quantity produced.

That’s what I would like to show you on the data. The science and Engineering Indicators issued by the National Science Board are a very nice source that regularly produces and traces that kind of data. Here (*graphic 1)* you see the number of articles produced in Science and Engineering, by country, from 1995 to 2009.



Graphic 1: S&E journal articles produced, by selected region/country, 1995-2009

First of all, good news for Europe, we’re still topping the charts; we’ve been above the US since 1994 in terms of number of publications. But of course, if you look at the more spectacular growth, you notice China: of course it is still down because it came from a very low position, but it’s actually the growth we should be looking at. We see it is bigger than the growth of other Asian countries, such as Japan, and it also explains why the Asia 10 (including Japan and China) is already almost as big now as the USA.

So there definitely is an important rise of Asian countries, such as China, but also some Asia 8 countries like South Korea or India.

This rise of China on average, in scientific publications, is very much tied to specific fields. On average, its biggest share in publications is in the material sciences (a field that also represents the highest growth rate), followed by Chemistry, Physics, Mathematics, Engineering, Computer Sciences and Geosciences. So publications are highly tied to the disciplines that most

China is much weaker in the medical sciences. Their growth in publications is slower and their output smaller, which is important because that’s where the USA are very strong. Recently, China started to get more into medical sciences, at least more in the bioengineering parts of medical research.

Note: the social and economic sciences are no disciplines of interest for the Chinese… That’s another area where they are not strong and also not making much literature about.

We will particularly care about average data in all fields and look at which percentile of the citation distribution the different countries or regions place each other, and then who is strong and where.

All fields	Share in all articles		Share in TOP 1 citation pc		Citation in BOTTOM50 citation pc	
	1998	2008	1998	2008	1998	2008
US	34	29	62	52	30	25
EU	35	33	25	30	34	32
Japan	8.5	7.8	4.3	4.5	9	8.5
China	1.6	5.9	0.1	2.5	2	6.7
Asia-8	3.6	6.8	0.3	2.2	4.5	7.9

Engineering	Share in all articles		Share in TOP 1 citation pc		Citation in BOTTOM50 citation pc	
	1998	2008	1998	2008	1998	2008
US	30	21	49	38	28	19
EU	30	29	29	25	29	27
Japan	12	10	9	6	12	11.5
China	3.1	10.4	1.3	10.6	3.4	10.6
Asia-8	7.9	14.1	2.2	10.6	8.5	14.9

Graphic 2: USA still dominant, but growing non-US impact

If we look at the TOP 1, that is the publication that gets the highest number of citations (we know that it's the really top researchers), we see the USA still owns the dominant position: they came out with 62% of TOP 1 citations in 1998; in 2008, it was 52%, so obviously declining, but they are still very high and represent more than half of the TOP 1 cited publications.

For the EU, we beat the USA in terms of number of article publications, but if you look at the TOP 1, we only represented 25% in 2008. So are slowly catching up, so that's the good news, but it's still only 30% so we still have a long way to go.

Then if you take a look at where China stands: it was nowhere in 1998 (0,1% of TOP 1 citations) and is quickly catching up in terms of quantity (5,9% in 2008) – not so much in quality – but you do see that their share is also gradually increasing in the TOP share, although it is still very low (2,5% in 2008). And in the BOTTOM50 percentage, they are also catching up.

This is the general outlook, but we can also look at the specific disciplines separately and remember China is very focused on specific segments of scientific research where it wants to improve its position. So engineering is definitely a discipline of interest for them.

There you see that in terms of shares the USA are not so strong – they are not particularly specializing in engineering; same thing for the EU. Asia is much stronger, on average, in terms of engineering, China represented more than 10% of all publications in engineering in 2008, and also more than 10% of TOP1 citations in that discipline, so China is not producing only the low-quality segment in the engineering articles, they have also caught up substantially in the TOP 1.

What is true for engineering is also true for other fields like Chemistry or Material Sciences, so China is catching up much faster in all fields that it wants to focus on, including quality-wise.

Another way of showing the catching up of Asia and the EU is the Index of highly cited articles by selected field and region or country, on the same period 1998-2008. If you reach the “expected value” of 1, it means that your share of the TOP 1 publications is as you would have expected on the basis of your share in overall publications. If you are above 1 it means you are over-represented in the TOP 1 and that you are specialized in high quality outputs.

Overall the USA are still holding the top positions, with EU slowly catching up but still below the expected value in all Science and Engineering disciplines. In the particular disciplines, there’s a big jump forward for Asia 8 and China in Chemistry, Engineering Physics. So China is not that strong (yet) in terms of quantity, but they are progressing on the quality in the fields it chooses to stimulate.

That’s for the quality dimension. Now **another important element to take into consideration is the frontier, where new science is being created.** It is of course a bit more difficult to find indicators about what new science is actually produced and where.

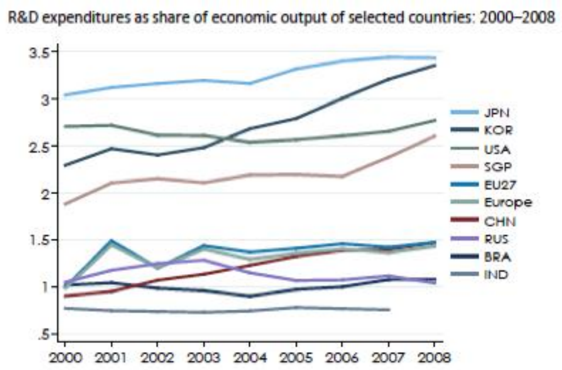
Thomson Reuters published a study called “Research Fronts” and devoted to emerging areas of research, core papers that are fundamental, new and frequently cited by a group of recent reports and scientific followers. They check where these foundational core papers originate from, and then they publish all kinds of foundational core papers.

A few examples show that the USA are also very predominant on the frontier (93% of Phase 0 clinical trials for cancer therapy in 2007, 85% of publications in the Silicon Carbide Ceramics new discipline in 2006…).

Clearly, in terms of output, that is where science is being produced, there are important shifts going on. And this is partly the reflection of differences in scientific input.

That is why China is growing, and it is also definitely related to how many resources a country is ready to dedicate to science. So we also need to consider the increase in scientific inputs, that is funding, and also how much researchers and PhD students are put into the system.

You all know the numbers in terms of R&D expenditures relative to GDP. Graphic 3 shows Japan and South Korea are holding the top of the chart in terms of R&D investment as share of their economic output. The USA are still dynamic but at a lower level. Then you have Europe, that continues to hover around 1,5% and doesn’t seem, despite it’s peaks in 2001 and 2003, to get in the movement. The red and steadily increasing line is of course China.

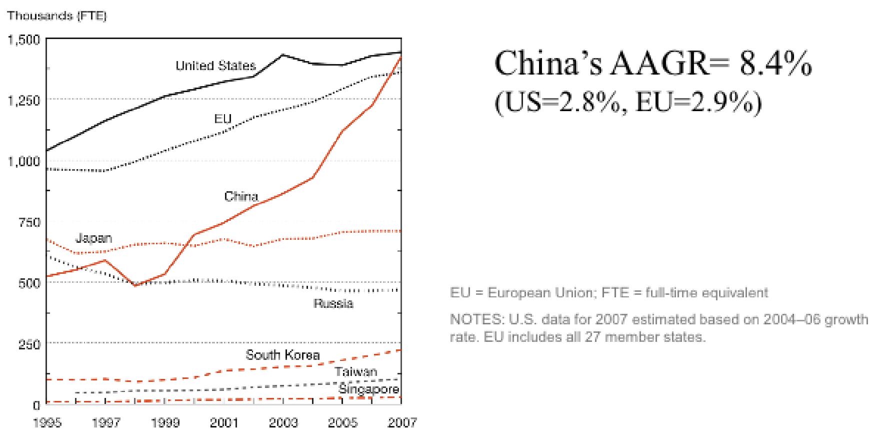


Source: UNESCO.
Note: Europe includes the EU-27 plus Norway, Switzerland, Albania, Bosnia-Herzegovina, Croatia, Iceland, Serbia, Turkey.

Graphic 3: Trend in World R&D to GDP ratios

These are totals so we don't know how much goes to science.

If we look at R&D workforce (Graphic 4), there again the rise of China is very spectacular. The pool of researchers working in that field is about the same size as in the USA. As for Russia, there is no real dynamic so it's one on the weak countries on that perspective.

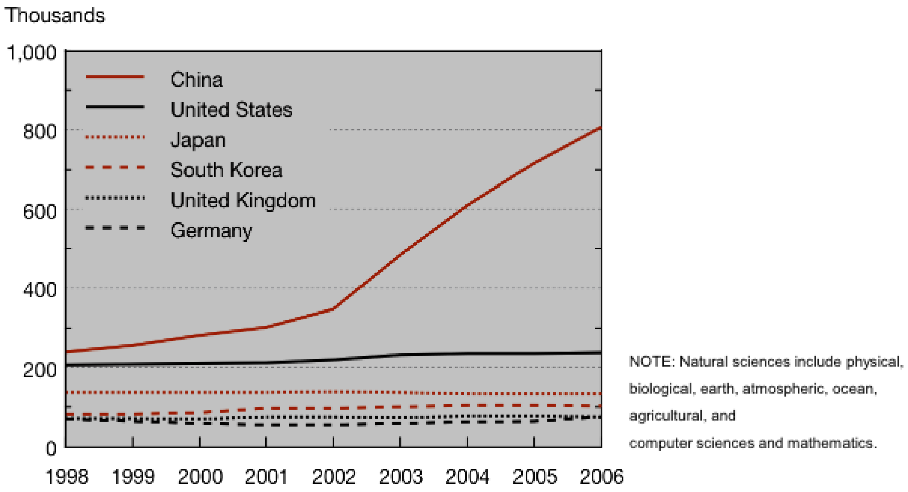


Graphic 4: R&D workforce (Source: NSF, S&E Indicators 2010)

What is also interesting to look at is the number of researchers and students trained for research positions (PhD degrees, and where they are produced). This is not based on the nationality of the students, but on where the diploma is obtained.

Of course the USA still are the largest country where PhDs are produced, even though, aggregated together, EU countries produce more (but NFS counts the countries separately). It's interesting to notice that this figure is the total for the US, meaning PhD produced by American and foreign students. If you look at the share of foreign US PhDs, we see it now outnumbers the US citizen's share. So the US generate the more PhDs, but they actually train more foreign students than domestic ones, and lots of these foreign students come from the new poles, especially Asia.

Graphic 5 shows PhD degrees produced in China, as registered by NSF. You see how spectacularly it has risen. Again you can question whether it's quality PhDs that are produced there, but quantity is there, and growing.



Graphic 5: First university degrees in natural science and engineering (1998-2006)

This rise in the number of PhDs is also the reflection of the increasing investment on Bachelor's degrees' education. If you take a look at the first university degrees in natural sciences and engineering (and again, that is where China puts the emphasis on), you see where this pool on engineers is coming from.

Clearly, China is also investing heavily in science training and education to improve its publications output.

It's nevertheless a very unequal scientific landscape: although there is a growth in the number of higher education institutions, China is also making a quality segregation, with vey well and very badly funded institutes: only 6% of the 1,700 chartered institutes of higher education, classified "Project 211", take up 70% of the scientific research funding and represent 1/3 of the undergraduate students, 2/3 of the graduate students, and 4/5 of the doctoral students.

Chinese authorities clearly want these institutes to become the biggest and most advanced in the world. And today, what is going on in the country science-wise is happening there.

The question is: what do these new trends and this shift in the scientific research landscape imply?

What implications for the science process itself? Will it be positive for science? Will it stimulate scientific activity and production? Will science be more effectively produced? Do we see more collaboration going on? Do we see the market for scientific talent becoming more mobile (for students and researchers)?

Effects beyond science are also important to consider: new technologies, innovations, firms generated in the new scientific hotspots, but also multinational firms locating R&D labs close to those new poles. We also know that companies are looking for scientific institutes for external sourcing. So, how does this geographical shift affect firm strategies?

Does globalization or multipolarity lead to more or less mobility? With globalization, there are more places to go to, but also more students and scholars everywhere, so less need to take them from other countries. Positive or negative? It all depends on how important the “push” factor is, that is how much a student or scholar wants to get away from a bad position for a better place, or simply wants to work in the best institute possible.

Let’s take a look at the data. First element: the number of foreign tertiary students going abroad continues to increase (+50% between 2000 and 2005). Not surprisingly, the major source country is China, by far, followed by India, and the major destination is still the US, followed by the UK. We also see that the flow between China and the US is far from curbing, since AAGR took 8,5% between 1997 and 2008. Despite the rise of China, you don’t see less Chinese students in the American campuses than ten years ago. You actually see more of them.

PhD students are the most mobile internationally; they are also the most interesting for us since they are the future researchers. There again the major source country is China, and the major destination is the US. Here again, no drop whatsoever in the number of Asian students coming to the States to graduate.

We do also have some data on the EU – I’m not talking about intra-Europe mobility, but really about students from outside the EU coming to Europe to get a PhD –: 5% of the doctoral candidates come from outside the EU (with 17% coming from Asia, Africa and Latin America). The UK attracts most of the Asian students, France is also a major destination, especially for students from Africa, and Spain is the first destination for Latin Americans.

Although there are more and more Asian students studying in the US, there is also evidence that students are massively returning to China. To increase that return rate, government institutions offer positions, funding and preferential tax treatment for overseas talent to come back and work in China. The question is when do they come back? Is it just after graduation, or in later stages of their career? This is important to know who benefits from these talents.

The US are very anxious to trace this data on foreign recipients of American PdDs. Unfortunately in the EU we don’t trace that kind of information – and I really think we should start doing it.

China is again the main source of foreign PhDs in the US. Chinese and Indian PhD students in the US record the highest stay rates (93% in 1986-99, 91% in 2004-07), significantly higher than EU stay rates, and this has only marginally decreased over time (Source: NSF, S&E 2008-2010).

(…)

The students that come to the US for a PhD almost all want to return, especially the Chinese, also because China is catching up, but it doesn't show in the data yet. At the time of graduation, how many non-US students have plans to stay? You see that earlier on, it was almost all of them, and the share hardly decreased. We have almost the same share of "stayers" amongst the Indian students (90% in 1996-1999, 89% in 2004-07). A vast majority of 75% of European students also wish to stay in the States after they graduate.

This is not to say they don't want to return, it's just that, upon graduation, they want to continue to build up their scientific abilities in the US, get a post-doc position, and only return later in their careers. But that's more difficult to trace, since unfortunately the US don't trace that information, and there is no precise data on the Chinese side either.

This also means that the US wish to keep those foreign talents in the hope to have them contribute to the quality of American scientific research. Actually the US are really worried about not having their foreign students anymore, because they would really lose a substantial part of the scientific machinery.

The share of temporary residents staying at US universities in post-docs positions rose from 51% in 1993 to 57% in 2006. They still represent the majority of the scientific post-docs workforce in the US.

The share of Asians in academic positions also increased in US universities, since it more than doubled between 1981 and 2006, jumping from a little less than 8% to 16,6%. It is important because these positions will also attract new students to the US campuses, and labs.

Of all science and engineering workers with a PhD, a majority (51%) are foreign-born. Foreigners also represent an important share of the non-academic science and engineering workforce. Only 54% of them obtained their PhD as highest degree in the US. That means the US are attracting a workforce that is not only composed of the students they trained, but also students trained elsewhere.

Again, if the quality of the PhD education is improving in all the countries, a vast majority of the Chinese students, once they have their PhD, still want to go to (or stay in) the US to push their training further.

So, contrarily to what you might expect, it also means the US could actually gain from this situation and attracting the best PhDs trained in other scientific poles.

According to the numbers, there are no signs, as yet, that the rising power of China's own scientific capability has significantly affected the mobility patterns of Chinese students.

This tends to show that the "pull" factor (scientific capacity of a host country) matters more than the "push" factor (lack of scientific capacity in the home country). It's not because of a lack of scientific capacities that they go abroad, it is because they are still attracted to the top quality that is being produced in the US.

An increasing convergence doesn't necessarily mean less international mobility; on the contrary, it could make international mobility even more rewarding.

As long as the US benefits from the pull factor and stays at the frontier, they will also benefit from both foreign and local talents. This means the US science base still pulls benefits from this multipolarity. Foreign students really are a critical source of the US' Science and engineering workforce, to a point where the US science supremacy is increasingly built on international talents.

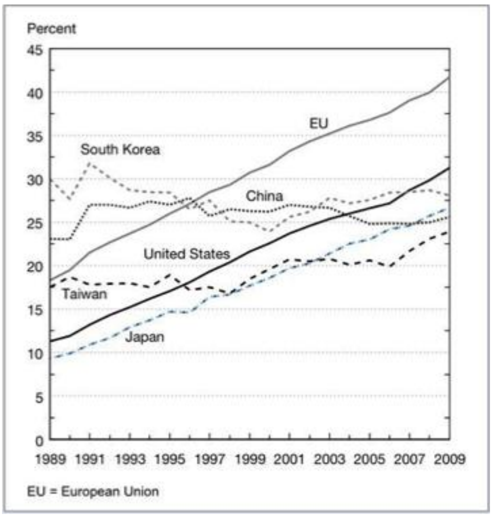
It is not only a matter of number, since foreign-born students disproportionately contribute to US top science. Sparkly selection story here: they are two times more likely to be a "most cited author" and almost two times on citation classics.

As long as the US can keep on attracting foreign talents, they will ensure their scientific supremacy, which also attracts new students from all over the world. It is a virtuous circle.

These benefits go beyond US science. These foreigners end up not only in the academic work sphere, but also in the private corporate workforce, where they establish international networks for recruitment, collaboration and ideas development, and many studies show they also often contribute to start-ups and patents.

International mobility seems on the rise. And if you look at international co-publications, again, as you would expect, scientific publications are increasingly being produced on a global scale.

This could mean that the poles matter less: since they collaborate, it doesn't matter where you are coming from if you can work along with these poles. But despite the increasing of international collaboration, the patterns of scientific collaboration are sticky and only change gradually. New poles are only very slowly entering into these old networks. It is particularly the case with China, which registers an important growth and mostly collaborates with the US. The EU is lower on the Chinese radar screen. To me, this fact is very much related to the easier mobility between those countries.



***Graphic 6: Research articles with international co-authors, by selected region/country/ economy, 1989-2009 (Source: National Science Board,* Science & Engineering Indicators 2012)**

On graphic 6, showing the rise of multipolarity with the percentage of internationally co-authored research articles by region or country, you see EU's curve is the highest, and on the rise. The US are also increasingly collaborating on an international level; it is rising as fast but still beyond the EU. That is on top of the fact that it is already very international locally. Most of the strongest local ties are still between TRIAD countries.

You also see that China is almost not increasing here. With the rise of the total number of publications, the share of international outputs doesn't grow, and stays approximately at the same level. It also means the national networks are growing in China.

Of course, what is more important is to know who collaborates with who and if new networks are created between dominant poles and new ones.

In order to know this, we calculated indexes of important international pairs, and corrected the number of internationally co-authored productions with the scientific size of the countries involved in each pair.

Table 4: Collaboration trends; International Collaboration Index for selected country pairs (1998-2008)

With US	1998	2008	With China	1998	2008
US-UK	0.67	0.74	CN-UK	0.58	0.52
US-GER	0.68	0.68	CN-GER	0.6	0.44
US-FRA	0.56	0.6	CN-FRA	0.39	0.38
US-JAP	1.03	0.89	CN-JAP	1.53	1.38
US-CN	0.82	0.97	CN-US	0.82	0.97
US-SKOR	1.38	1.23	CN-SKOR	1.72	1.17
US-INDIA	0.92	0.79	CN-INDIA	0.98	0.64
Intra-EU	**1998**	**2008**	**Intra-EU**	**1998**	**2008**
UK-GER	0.68	0.86	NL-BEL	2.5	2.68
UK-FRA	0.73	0.87	NL-GER	0.95	1.29
UK-IT	0.86	1.04	GER-PL	1.15	1.34
UK-NL	1.05	1.27	GER-CZ	1.27	1.46
FRA-GER	0.74	0.91	PL-CZ	2.15	3.48
FRA-IT	1.12	1.34	SE-FIN	3.39	3.98
ES-IT	1.38	1.63	SE-DK	2.88	3.38
ES-PT	2.55	2.9	FIN-DK	2.36	3.15

Source: Bruegel based on NSF, Science and Engineering Indicators 2010. Note: an index of international collaboration corrects for the effects of the unequal size of countries' research establishments. Values above '1' indicate greater-than-expected rates of collaboration.

This table, published a few months ago, gives you the collaboration trends with the ratios of who collaborates with who. If the figure is larger than 1, it means you collaborated more than expected on the basis of the number of publications. If it's below 1, you're underrepresented.

Of course most of Europe's scientific publications will be with the US, since it's the largest actor, particularly if you take into account the size of the US in scientific terms, and still the dominant pole in terms of frontier research.
You notice that most of the countries collaborating with the US are actually European countries. You would expect the EU to also be an important pole. It is in terms of absolute numbers, but if you correct with the importance of the US, it comes on top of the EU countries, including France.
The US are overrepresented with Europe's usual partners, such as South Korea, Taiwan, Israel, Mexico, or Canada. It is almost at par with China, with an index of 0.97, showing that the collaboration between the US and China is following the trend of growth in publications.

If you take a look at the Chinese perspective, you'll see a mirror image regarding its collaboration with the US, almost at par. It also shows the Asian dimension, with an overrepresentation of Japan, Singapore, South Korea, Taiwan, and to a lesser extent Australia. Again, the EU countries are much less represented. For Germany the curve even goes down. France is almost stable; it is following the growth in Chinese outputs, but at too low a level.

The EU indexes show the predominance of intra-EU collaborations that are still preferred, and rising, mainly because ERA is doing a good job. On average, most of the intra-EU collaborations are above par.

Obviously, the geographic proximity plays an important part in this trend. There is an important Scandinavian link, for instance. Germany is also very much related to its Eastern and Northern neighbors (Netherlands, Belgium…).

What is also interesting is that the ratio increases over time. **The strong positions that Europe already had seem to be reinforced with the ERA network.** So EU is especially strong in intra-bloc collaborations, also with Russia. It is very well represented with the BRICS, but unfortunately Russia is not one of the most dynamic countries in terms of science, Scandinavia. You will also notice, again, the EU is below par with the US and China.

Taking stock and suggesting Policy implications

The numbers are very clearly showing there are shifts going on in terms of new poles becoming more important scientifically, with the rise of the Asian poles, especially China.

The EU, as a group, jumped the US in terms of number of publications since 1997, and is catching up with the US in citations, that is quality-wise.

The US remain a very important pole, but is slowly more and more challenged in quantities of publications, although still less so in quality.

The effects of this shifting in the geography of science and these multiple poles is, to me, a win-win game for science, at least for a number of players.

Despite the rise in its local scientific capacity, China's absolute outflow of students has not diminished. On the contrary.

The US continues to attract the lion share of foreign brains, at all stages: students, scholars... With a high stay rate, foreigners contribute substantially to the build up of the US scientific and economic capacity. That is a very clear sign the US continue to benefit from this new multipolarity, at least for the moment.

Returns rates to China, if that is true, are also on the rise in the later stages of their students' careers, and therefore also contribute to build up the Chinese scientific capacity. The Chinese are also definitely gaining from this multipolarity, also using its links with the US to improve its capacity.

A multipolar science world is in the making, with a strong and virtuous US-China nexus.

The question is: what will the future bring? Will it be multipolar, with the EU remaining an important pole? Or will it basically be, because of this virtuous US-China nexus, a G2?

This G2 system is obviously a virtuous circle, where China can continue to grow by sending out the best of its talents to the frontier, in the US, and then, when they are sufficiently trained, bring them back to China. At the same time, it allows the US to maintain a dominant position, as long as it can keep on attracting foreign talents, at least long enough so that they contribute to the frontier research workforce, with benefits for

the US science, but also for their country of origin, where they come back more skilled in these competitive fields.
So on one hand the Chinese pole is continuing to grow, also in quality, sending out its talents to the best of the world, and attracting the best back, connected to the best in the world. And on the other hand the top frontier research position of the US pole will continue to attract the best of foreign talents, contributing to the US science, technology and economic success and connecting the US to the best hotspots in the world.

What about the other poles?
We can definitely speak of an Asian pole and an Asian integrated market of science with Japan, India, and other Asian countries, even though Asian regional integration is not straightforward.

Concerning the EU, the first question should be: are we one pole? Is the ERA sufficiently materialized? Do we have one European pole, or is it just a collection of loosely connected nodes, with some of them poles?
Next question is: even if the EU was perfectly integrated, would the EU-pole be equivalent to and as strong and efficient as the virtuous US-China nexus?

The growing multipolarity could create a G2, but the future might also bring a G1.

If you take a look at China's ambitions for the 2011-2015 period, this 12th five-year plan is putting the emphasis on Innovation, and especially on new strategic sectors like green science, IT or biotech, with the objective to build up world class universities and gain science leadership by 2050. It's an option we should also consider.

Returning to the EU, I'll draw some tentative policy implications. We cannot ignore what is going on and really need to engage in this multipolar world as fast as possible to try and benefit from this trend and turn it into a virtuous circle as well.

The only way to achieve this is to aim for excellence in science and technology capacity; that is the pull effect that will allow foreign students to be attracted to the EU. It needs to become a hub for in- and out-going flows, and a bargaining chip for scientific cooperation, trade and ideas networks.

To build excellence, cooperation should be supported through bottom-up excellence support, rather than top-down support. We need to pen circulation inside EU to allow specialization in hot spots, to attract foreign talent, and to allow diffusion of results while avoiding circulation diversion.

Those intra-EU efforts should not distract us from the extra-EU collaborations. Openness at the borders is very important, for international students as well as scholars. Mobility of researchers is crucial for the creation of networks and scientific cross-benefits. So we need to speed up the ERA Policy agenda, with a focus on external openness, and intra-EU mobility driven by excellence criteria.

When Freeman (2005) asked a Harvard physicist, who had published important work in co-operation with overseas scientists and engineers, "so you are helping them catch up with us?" the scientist replied: "no, they are helping us keep ahead of them".