INTERNATIONAL RESEARCH COLLABORATION AFTER THE UK LEAVES THE EUROPEAN UNION

A report from Digital Science Consultancy for Universities UK

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SUMMARY OF KEY POINTS

1. International collaboration is integral to creating world class research with impact.

International collaboration is increasingly synonymous with excellent research. Working internationally enables individual academics to increase their impact and nations to pool talent and resources to address global challenges that no country can tackle alone.

Research shows that international research collaboration is also vital for individual institutions that aim to produce outstanding research, and that the increase in such collaboration has been very rapid indeed.

International collaboration increases citation performance because combined talents produce more innovative and useful outcomes. The global reach of the UK's universities is therefore a source of strength that increases the quality and efficiency of the UK's national research base.

2. Research is produced by people, and successful collaborations are driven by researchers – but they need support from institutions and appropriate funding.

Research is not like trade or finance. High-quality research partnerships may be enabled by international agreement, but they are implemented via the willing and mutually beneficial agreement of principal investigators and their research groups.

It is of limited benefit to develop overly complex strategic analyses of 'who Britain's best new research partners' would be. A good link for engineers may not be a good link for clinicians and the research economies in which UK researchers find profitable partnerships are themselves increasingly collaborative.

However, well-structured and flexible funding mechanisms are required to support collaboration, and can influence strategic decision making.

3. It is vital that UK-based researchers have the ability, support and resources to collaborate with the best partners – wherever they may be.

UK research is global in focus. Our institutions already collaborate with partners in a range of countries, both EU and non-EU; the emphasis is on working with the best partners, those that are most appropriate for the specific research being undertaken.

It is important to recognise that international collaborative partnerships in research with other EU member states collectively make up the largest pool of collaborators. Research undertaken with EU partners like Germany and France is growing faster than with other countries – hence while it is vital that the UK takes every opportunity to be truly global in their outlook, the importance of collaboration with EU partners should not be underestimated.

Policy and funding for research collaboration should support flexible, effective collaborations with impact, wherever partners are found – and this must include both EU and non-EU partners.

4. **There are a number of challenges that can be addressed to help reduce the barriers to research collaborations between UK-based researchers and international partners.**

More could be done to facilitate international research collaboration, and this requires more than just funding. Better information on the capabilities and research strengths of both UK-based researchers and research organisations and potential collaborators is needed; the importance of cultural barriers to international research collaborations needs to be better understood, and any differences mitigated; and the importance of both policy and funding stability in nurturing effective research partnerships must be recognised.

5. **One mechanism for facilitating effective research collaboration would be to create more agency-level bilateral agreements – built around flexibility and with funding attached.**

Regardless of access to EU programmes, enhanced international collaboration could be facilitated by either agreeing partner funding or at least avoiding 'double jeopardy' through, for example, a coordinated application process at agency level.

FOREWORD BY UNIVERSITIES UK

This paper sets out some initial views on the opportunities and challenges that exist for UK research in the post-Brexit landscape. It suggests ways in which the government, research funders and universities can build on our globally recognised research excellence to support and enable international research collaborations that enhance the quality, prestige and impact of UK-based research and researchers.

As the government looks to minimise the turbulence and maximise the opportunities associated with leaving the European Union, British universities have a vital contribution to make to a successful, dynamic and internationally competitive post-exit United Kingdom. Universities can play a central role in driving inclusive economic growth locally, regionally and nationally; improving productivity as part of a new industrial strategy; and strengthening our international trade and diplomatic relationships across Europe and the wider world.

The UK's scientific research institutions are ranked second in the world for quality. With only 0.9% of the world's population, the UK produces 15.9% of the world's most highly-cited articles. We (the UK) also ranks first in the world by field-weighted citation impact (an indicator of research quality). Universities support the UK's soft power and global partnerships: many leading international figures are alumni of British universities and our universities are connected with businesses, governments and research partners worldwide.

The positive contribution of UK higher education to the UK economy and society will be greatest if British universities are magnets for international talent, are welcoming to international students and are leaders in international research collaboration.

To support UK research, the government should prioritise developing funding arrangements and enhanced support for research collaboration. This should not be framed as a choice between collaboration with European partners or with partners across the rest of the world. We should look to developing new networks and funding arrangements that support collaboration with major research powers outside of Europe, alongside ensuring continued close collaboration with European partners.

The primary focus should be on delivering excellent research. Provided the 9th Framework Programme (FP9) for research and innovation (the successor to Horizon 2020) maintains a focus on excellence then the UK government should seek access to it, as well as influence over its future shape. This should be alongside new funding sources to incentivise and enable bilateral and multilateral collaborations with high-quality international research partners beyond the EU.

Such an approach would benefit from being underpinned by a cross-government approach to supporting international research (as part of a wider international research and education strategy), covering engagement with both the developed and developing world, and drawing together and building on the disparate funding mechanisms which exist for international collaboration currently. This more joined-up and strategic approach should include promoting research collaboration opportunities (through the new Department for International Trade) as a central pillar of the UK's offer to overseas governments and businesses.

INTERNATIONAL RESEARCH COLLABORATION AFTER THE UK LEAVES THE EUROPEAN UNION

1. International collaboration is integral to creating world class research with impact.

Research has progressed through three ages: the individual, the institutional and the national. Nations competed to be at the cutting edge because this contributed to the wider economy through knowledge, new processes and products. Today, we are entering a fourth age of research, driven by international collaborations between elite research groups. This will challenge the ability of nations to conserve their scientific wealth either as intellectual property or as research talent (Adams, 2013).

Internationally collaborative research publication has increased for the UK research base as a whole, in line with other research economies (Adams, 2013). The balance of partners is dynamic and collaboration has risen more steeply with the EU than with the rest of the world. The most research intensive universities are more collaborative than others but the trajectory of collaboration is progressively upwards for all universities. Less than half of the UK's output is now purely domestic and the domestic share is much less for some leading universities.

Analysis has shown that while total research output has more than doubled over 30 years for some established economies, the global trend has been for more of this research to be undertaken as part of international research collaborations (Adams and Gurney, 2016). While around 90% of UK output was domestic in 1981, less than half is now produced domestically. This means that almost all the growth in output of the last three decades has been produced by international partnerships.

Publications with international co-authorship are on average more highly-cited than UK domestic publications (ibid.). This enhances other differences in research performance measured by citation analysis, with the consequence that there is a significant correlation between the average normalised impact of a university's papers and the share that is internationally collaborative.

As the volume of international collaboration increased, these papers have increasingly enhanced the UK's relative international performance in comparative citation analyses. The average citation impact of domestic papers has been only slightly better than world average, but that of internationally co-authored papers has been higher on average and that difference has increased.

Research can also be a form of diplomacy, leading to alliances and memoranda between national academies. For universities, international links create esteem and demonstrate the wider engagement and status of an institution, helping to attract students and staff from an international catchment. At the level of individual researchers and research groups there has also been a significant growth of collaboration, much of which will have developed outside the frameworks of formal agreements. Research advances faster and further by combining your agenda with partners, but it is not cost-free since it involves not only tangible resources but time to discuss and agree shared priorities. Collaboration is therefore limited to the number of sustainable and rewarding links that can be developed.

2. Research is produced by people, and successful collaborations are driven by researchers – but they need support from institutions and appropriate funding.

Productive discussion of the options for collaborative research must recognise that it is delivered by individuals, not countries. Countries commission and pay for the public component but they depend on individual motivation for its success. Individuals determine their research choices on the basis of alternatives that are more or less likely to further their career, choosing those that offer the best opportunity for significant advance and are likely to be funded. This amplifies the problem of creating and sustaining links, because of the need for both parties need to be funded. Sir Gareth Roberts reported on the constraints around UK collaboration with the USA and Germany and highlighted the problems of 'double jeopardy' (Roberts, 2006).

For example: EU links exist because many individual UK and EU researchers at well-funded, research-intensive universities decided that such collaborations provided mutual net benefits. Alternative partnerships may be increasingly difficult to negotiate and likely of lesser priority, and perhaps quality, than those already in place. Suitable alternatives would need to have parity of esteem with the UK; to be attractive collaborators; and to enhance both parties' research investment. They would need to have the resource capacity for engagement with UK researchers: EU collaboration proliferated because mutually assured Framework Programme funds supported it.

Regional networks counter-balance the older trans-Atlantic US-Europe axis. China has partnerships, with economic and cultural support, across Asia-Pacific and into Australasia: Australian collaboration is increasing faster than with the UK. Egypt and Saudi Arabia are the key regional axes across North Africa and the Middle East (Adams et al., 2011). Research in Sub-Saharan Africa is dependent on collaboration elsewhere but has limited resources (Adams et al., 2014). Brazil (a relatively frequent UK partner at 2,000 co-authored papers per year, > 1% of UK output: Table 1) is the axis of an emerging Latin American network with Argentina, Chile and Mexico (Adams and King, 2009). The Brazilian government has, however, announced a 44% cut to the science budget in March 2017 (Nature, 2017). Despite the UK's research excellence, it may not always be a partner of choice if major regional economies provide accessible alternative networks.

Asia-Pacific is an area with recent significant increases in research investment and long-standing UK ties with hubs such as Singapore and Hong Kong. South Korea, Taiwan and Vietnam are potential partners of recognised research merit.

- South Korea's research output has grown by more than 50% since 2007, mainly through domestic growth. The USA co-authors half of its international publications and no other nation has a strong position (11,344 papers with the UK in 2007–2016, 0.70% of UK output). (Kwon et al., 2012)
- Taiwan's output grew mostly via international collaboration, on the European model. The US, China and Japan are main collaborators but the UK share is greater than other EU countries (7,334 papers with UK in 2007–2016, 0.45% of UK output).
- Vietnam is small but has quadrupled research output in ten years, up to three-quarters of which has been internationally collaborative. Existing partnerships are substantial and France is its most frequent EU partner (1,815 papers with UK in 2007–2016, 0.11% of UK output).

The most likely opportunities for innovative collaboration with research-intensive economies with capacity are to be found in South Korea and Taiwan. They offer a strong and well-funded technology base and excellent university systems with a highly-educated workforce and a high rate of English-language speakers. To offset this is the challenge of geography, the proximity of regional partners, and cultural differences.

Individual and group research partnerships across the globe require no national targeting to identify mutual esteem. What is lacking, however, is a funding mechanism that would translate possibilities into realities. These are not, of their nature, structured collaborations whereas official funding systems prefer to work with well-defined structures and criteria.

3. **It is vital that UK-based researchers have the ability, support and resources to collaborate with the best partners – wherever they may be located.**

International collaboration accounts for half the publication volume of the leading research economies (Wagner and Leydesdorff, 2005; Adams, 2011). National growth depends on collaboration and the most highly cited papers are found in the international network, which is the leading edge of a fourth age of research innovation and organisation (Adams, 2013).

Most UK collaboration is with EU partners. In 1981, less than 5% of UK research publications had an overseas co-author. In the ten years to 2016, UK researchers published 1.6 million items in frequently-cited journals on Web of Science and half the output was internationally co-authored (Figure 1).

Collaboration is closely associated with exceptional performance. Collectively, UCL, Imperial, Oxford and Cambridge publish about one-quarter of the UK's research output. Their international collaboration has expanded more than the UK overall, to 57.7% of total publications in 2016 (compared to a 52.6% UK average: Adams and Gurney, 2016) and their collaboration with the EU is 35.3% compared to 30.7% (Figure 2).

4. **There are a number of challenges that can be addressed to help reduce the barriers to research collaborations between UK-based researchers and international partners.**

Experience in South Korea and Taiwan has shown challenges cultural barriers to collaboration. Visits to universities in those countries in 2010–2011 identified communication problems. There is sometimes uncertainty about the research profiles of UK universities (for example, a Taiwanese research group knew of work but could not find detail of the wider institutional research environment, while a South Korean university was serially redirected, to the significant embarrassment of its senior managers). UK universities need clear routes of communication with potential partners – at both institutional and sector level.

More recently, a 2016 South Korean visit organised by the British Council focussed collaboration discussions around biomedical devices, drawing on complementarity in UK biomedical research and Korean technological expertise. Development turned out to be culturally challenging, mostly due to the significant differences in research governance.

It is also clear that research collaborations often take significant investment of time and resources, on behalf of both individual research teams, research organisations and facilitating bodies. Therefore stability and certainty in both policy and funding environments should be seen as key facilitators of effective and impactful international research collaborations.

In summary, there are a number of high-level issues that can be addressed by stakeholders to support more effective international research collaborations. These include:

- **The provision of better information on research strengths, strategic priorities and potential synergies:** There needs to be better understanding and matching of research and innovation strengths between partners and potential collaborators, with clearer articulation of these and provision of contact points at the research organisation, funding agency and sector levels.
- **The influence of cultural factors should not be underestimated in making collaborations work:** Researchers working within different national contexts will have experience of different research cultures. These can be a source of strength and innovation, but also create challenges that must be understood, acknowledged and addressed. This requires time, but can be mitigated by the development of shared understandings, priorities and policy frameworks.
- **Stability, certainty and trust are required if successful international research collaborations are to be fostered:** Partners need to have confidence that the policy and funding environment will not be subject to unexpected or dramatic change after they have invested the time and resources necessary to develop productive and beneficial partnerships.

- **The circulation of people and ideas is fundamental to international research collaborations:** National policy frameworks of all partners must be flexible enough to support international exchange, enabling critical human resources – including technical expertise – to flow between systems.

5. One mechanism for facilitating effective research collaboration would be to create more agency-level bilateral agreements – built around flexibility and with funding attached.

The preceding sections have identified:

- The strategic problem of analysing nation-to-nation partnerships:
  - because individual researchers do not choose collaborators on that basis
  - because, at a national level, appropriate partners are already widely engaged
- The researcher's problem of acquiring funding for collaboration:
  - because budgets are not allocated on individual priorities
  - because collaborative links carry a double jeopardy

A research-led, administratively-sound alternative is agency-led thematic partnerships. Many memorandums of understanding (MoUs) already exist between UK and overseas agencies and reflect established common research priorities, so this is not a new idea.

The UK Research Councils (RCs) support missions reflecting UK strategic priorities. Their peer-based committees provide an excellent and experienced overview. Their awards' management systems provide the review and audit processes needed for accountable deployment. A bilateral agreement on common priorities between a Research Council, or other public agency, and one overseas is initiated by complementary research interests and furthered by mutual research standards. What many MoUs lack is the substance – a research fund – to back this up and enable words to become actions.

It is easier to agree to share these commitments where understanding has grown over a prior period. Brazil has invested substantially in biotechnologies, doubling its research activity in the decade after 2000 and creating a 'natural knowledge' research economy (Adams and King, 2009). Research Councils UK (RCUK) works in partnership with FAPESP, the Research Council for the State of São Paulo, to strengthen the existing research links between the UK and Brazil to help encourage and support proposals that involve international collaborative teams. The relevant MoU was first signed in 2009, in a move led by the Biotechnology and Biological Sciences Research Council, and its success led to renewal in December 2015 for five years to 2020. By avoiding double jeopardy in funding applications, the MoU removes some barriers facing international collaboration.

In Chile, the Science and Technology Facilities Council (STFC) has been managing the UK's membership of the European Southern Observatory. This longstanding and successful relationship could sensibly be extended post-Brexit into a wider but still thematic MoU to support other engagement between the UK and Chile. Nature (2016) drew attention to the status of Chile as a 'rising star' in the physical sciences.

Interestingly, Chile also encapsulates a particular challenge facing UK research – its graduation this year from the Development Assistance Committee's Official Development Assistance list means that it is no longer Newton Fund-eligible in the full sense, although it will continue to receive a lesser rate of funding available to support global projects). UK research funding beyond the EU is highly dependent on the ODA budget, which comes with limitations in terms of the research themes which can be considered and the countries to which major investments can be allocated. For a post-Brexit UK, new money without ODA restrictions is urgently needed to fuel collaborations with major partners that will not be eligible for

cooperation via EU funds, if continued Horizon 2020 access is secured, and that are not ODA-eligible.

RCUK has a MoU with the National Research Foundation of South Africa. As part of the UK-South Africa Newton Fund, this is intended to support opportunities to boost collaborative research that explicitly benefit both nations. The first strand of activity under the MoU was a joint PhD Partnering Scheme.

Such arrangements need not be restricted to agencies outside Europe or even to the public sector. NERC, for example has long-standing MoUs with the Department for Environment, Food and Rural Affairs, (inherited from the Ministry of Agriculture, Fisheries and Food) and with Shell, where there are common priorities around environmental research. Within Europe, RCUK works in partnership with Fonds National de la Recherche (FNR) in Luxembourg, to encourage and support proposals that involve international collaborative teams.

Figure 1: UK output has increased annually in the last decade but relative international collaboration has risen at the same time, from 40% to over 50% of that output. EU co-authorship has gone up to include over 30% of all UK papers. (source, Web of Science; analysis, King's College Policy Institute).

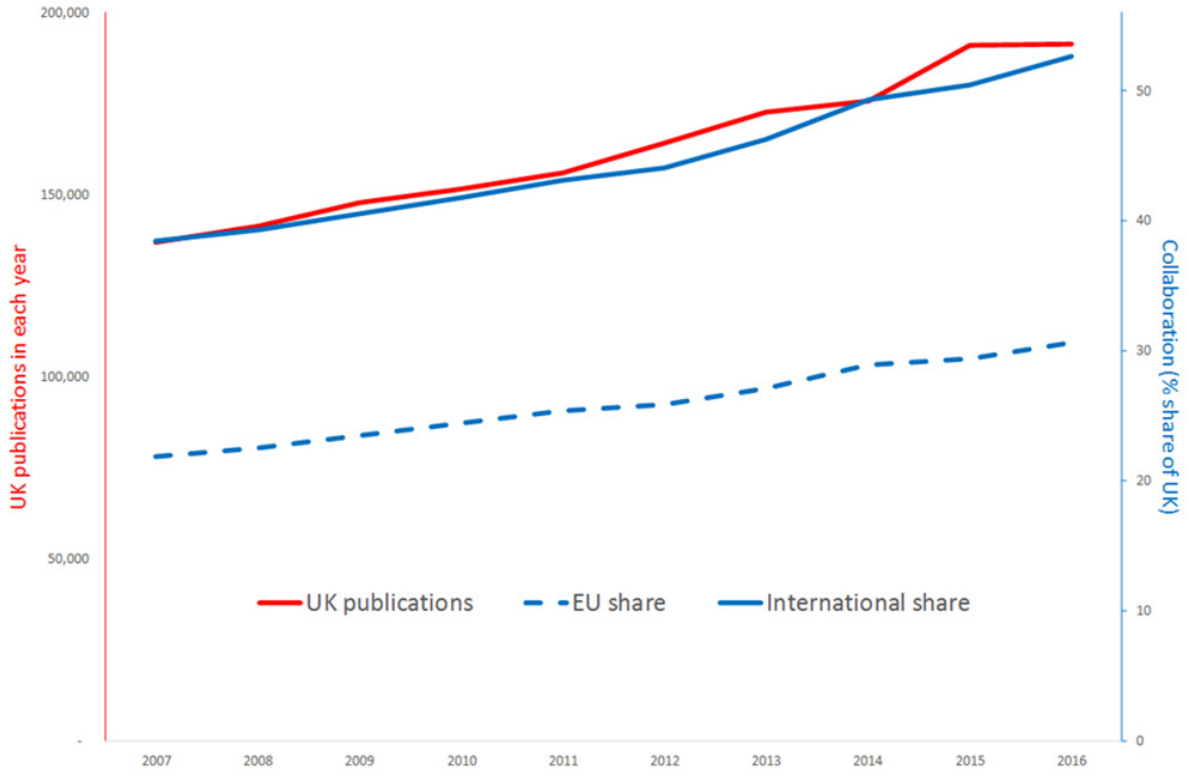

Figure 2. The trajectory of international co-authorship on research publications from Imperial, UCL, Cambridge and Oxford. Collective domestic output has plateaued at 20,000 publications per year while international collaboration accounts for their overall growth. (Data: source, Web of Science; analysis, King's College Policy Institute).

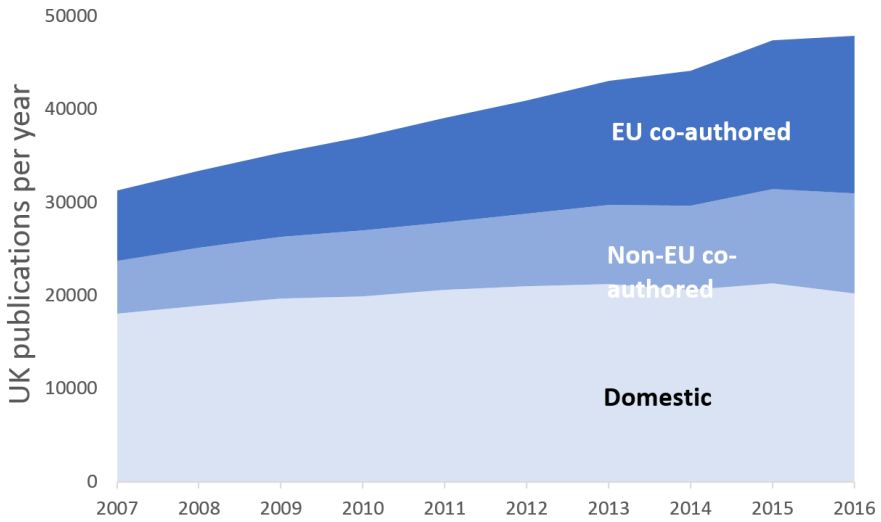

Table 1. Countries that have co-authored 1% or more of UK output (indexed on Clarivate Analytics Web of Science) during 2007–2016. Non-EU countries highlighted in bold. (Data: source, Web of Science; analysis, King's College Policy Institute).

	Publications	Share of		Publications	Share of
UK	1,628,970	UK %			UK %
USA	**223,157**	**13.70**	Belgium	33,279	2.04
Germany	114,556	7.03	**Japan**	**28,662**	**1.76**
France	82,849	5.09	Denmark	26,265	1.61
Italy	75,228	4.62	Ireland	20,739	1.27
Australia	**66,181**	**4.06**	Austria	19,201	1.18
Netherlands	64,484	3.96	Greece	19,019	1.17
Spain	60,134	3.69	Norway	18,709	1.15
China	**57,945**	**3.56**	**Brazil**	**18,358**	**1.13**
Canada	**56,256**	**3.45**	Poland	17,740	1.09
Switzerland	44,080	2.71	Finland	17,039	1.05
Sweden	37,625	2.31			

Table 2. Multinational co-authorship with at least one UK author, 2007–2016. Most publications are bilateral: for example, of 82,849 papers that UK co-authored with France, 15,835 were also co-authored with the Netherlands. (source, Web of Science; analysis, King's College Policy Institute).

UK and …	Germany	France	Italy	Netherlands
Germany	114,556	27,292	23,667	20,555
France		82,849	21,318	15,835
Italy			75,228	14,200
Netherlands				64,484

Table 3. The research publication output (2007–2016) of a selection of UK research-intensive universities. The table shows the total output and the count and percentage of those publications that had a co-author from another country in the European Union. (Data: source, Web of Science; analysis, King's College Policy Institute).

Institution	Total output	EU co-authored	% of output with EU co-authors
Imperial College London	94,828	31,419	33.1
University College London	124,161	39,221	31.6
Queen Mary University London	29,752	9,273	31.2
University of Edinburgh	58,824	17,773	30.2
University of Liverpool	36,378	10,964	30.1
University of Glasgow	41,565	12,348	29.7
University of Oxford	111,467	33,003	29.6
University of Cambridge	100,315	29,630	29.5
University of Southampton	43,493	12,845	29.5
Kings College London	62,967	17,685	28.1
University of Manchester	70,931	19,267	27.2
University of Bristol	43,832	11,517	26.3
University of Birmingham	48,811	12,823	26.3
Cardiff University	34,890	8,867	25.4
University of Leeds	41,474	10,140	24.4
University of Sheffield	41,492	10,107	24.4
University of Exeter	21,393	5,015	23.4
University of Nottingham	45,304	9,439	20.8

Table 4. Research publication output of three Asia-Pacific economies. The data are shown as the annual publication count on Web of Science and the percentage of those publications that have an international co-author. (Data: source, Web of Science; analysis, King's College Policy Institute)

	South Korea		Taiwan		Vietnam	
	Publications	Int'l %	Publications	Int'l %	Publications	Int'l %
2007	46,354	21.8	28,766	16.9	1,005	75.1
2008	48,410	22.8	31,412	18.3	1,306	70.7
2009	51,758	23.0	33,606	18.9	1,464	68.7
2010	53,955	24.6	33,262	20.4	1,607	73.6
2011	57,849	25.7	35,715	20.8	1,747	75.3
2012	64,954	25.4	37,831	21.6	2,334	70.8
2013	66,398	26.5	38,538	22.8	3,108	68.8
2014	71,381	26.3	38,547	24.5	3,345	70.9

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