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‘Estimating’ numbers?

A response to a paper by Samuel A. Hardy

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In a recent paper in *Cogent Social Sciences*,[1] Samuel A. Hardy (2017) has attempted a wide-ranging comparison of the efficacy of different kinds of regulations of metal detecting. In it, he attempts to estimate the number of metal detectorists active, whether lawfully or illegally, in several different European countries, Australia, Canada, New Zealand, and the USA.

He also attempts to estimate the ‘damage’ caused by their removal of artefacts ex situ. This, he does by first estimating the average amount of hours per year searched by the average metal detectorist, and then estimating the number of significant artefacts found per hour of searching. By multiplying these estimates, he arrives at the estimated number of significant artefacts removed ex situ per year in each of the examined countries, which he takes to be the ‘damage’ that is caused.

These estimates he then compares transnationally, and arrives at the conclusion that comparably permissive or liberal regulatory regimes are ineffective in minimising harm to the archaeological heritage.

Methodical and arithmetic flaws in Hardy’s (2017) paper

While I appreciate Hardy’s attempt, there sadly are serious flaws both in his methodology and arithmetic, and thus also his conclusions. Since he specifically quotes a recent paper on the matter that I co-authored (Karl & Möller 2016) as the inspiration for his method of estimating the number of metal detectorists active in different jurisdictions, I feel the need to respond directly to his paper.

Remarks on our methodology

The methodology Möller and I used (also see “An empirical examination of metal detecting”) in the paper cited by Hardy as an inspiration for his is based on a quite simple principle: the direct comparison of like data with like.

In our paper, we specifically explained why such a direct comparison, rather than a comparison of estimates, is essential for debates about regulation of metal detecting: estimates of the total number of metal detectorists active in any particular country can and do vary widely, frequently by an order of magnitude or even more (see e.g. for Austria the range from as little as 250-500 to as many as 10,000+ in 2010, Karl 2011, 120 fig. 5; cf. the range of between as little as 9,000 to as many as 250,000 for England and Wales, Hardy 2017, 15).

Comparing any estimates picked from these ranges with each other transnationally is obviously meaningless: if one compares, per capita, the lowest estimate for Austria of 250 active metal detectorists (1 metal detectorist per 34.340 inhabitants) with the highest estimate of 250.000 for

[1] *Cogent Social Sciences* is a ‘Pay to Publish’ Open Access Journal, which allegedly ensures high quality standards of papers published in it by a rigorous process of peer-review. As recently demonstrated by Peter Boghossian and James Lindsay (2017), that quality assurance process seems to be less efficient than desired. This is also demonstrated by the fact that Cogent Social Sciences refused to correct the serious arithmetical error in Hardy’s calculation of the number of metal detectorists in the USA, when I made it aware of it.

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England and Wales (1 per 232 inhabitants), then the latter obviously has 148 times as many active metal detectorists than the former. If, on the other hand, one compares the highest estimate of 10.000+ for Austria (1 per 858 inhabitants) with the lowest of 9.000 for England and Wales (1 per 6.432 inhabitants), the former obviously has 7.5 times as many active metal detectorists than the latter.

Thus, depending on which 'estimates' from these ranges one compares, one can arrive at totally opposite conclusions. Since arguments can be found for any of these estimates to be 'reasonable', comparing any such selected 'estimates' is extremely unreliable: one could compare 'estimates' which in one case represent as little as a few percent of the actual number of active metal detectorists in one country and in the other represent a multiple of the actually active community. Such comparisons, therefore, do not allow to arrive at any reliable conclusions.

For this reason, we proposed to compare data from the same kind of sources directly: of metal detecting internet discussion boards. While there is, of course, no guarantee that they actually do, there are several reasons as to why it would neem likely that the membership figures of such boards are representing – at least roughly – the same fraction of the community communicating about metal detecting in otherwise comparable countries. We have argued that this is for the reason that they fulfil similar needs of the respective communities in countries with similar societies; which makes it exceptionally unlikely that e.g. 100% of all active German metal detectorists are members of the largest subject board in their country, while less than 10% of their English and Welsh peers are subscribed to the largest equivalent board in Britain.

If that assumption that the membership of 'national' metal detecting discussion boards on the Internet represents – at least roughly – the same percentage of the actual number of active metal detectorists in their respective country is true, the board memberships can be directly compared, regardless of what the actual number of metal detectorists in each country is. This is for simple mathematical reasons: if a known figure A represents a particular fraction F of another, unknown figure X, its ratio to any other known figure B which represents the same particular fraction F of yet another unknown figure Y will always be the same as the ratio between the unknown figures X and Y.[2]

In short: **We directly compared the same kind of data, collected with the same method, in all countries we examined**.

Hardy's methodology compared to ours

Claiming that his paper's methodology is *"[f]ollowing a novel method of open-source analysis of detecting communities in Austria, Germany and the United Kingdom (Karl & Möller 2016)"* he states that *"searches were conducted to identify data on the size of detectorist communities"* (Hardy 2017, 8). Since Hardy intended to *"analyse the impact of detecting"*, he deemed it necessary in this context to first *"estimate the number of detectorists in any territory"* (ibid.).

Yet, the very point of our methodology is to avoid using unreliable 'estimates' in transnational comparisons, and especially avoiding unreliable estimates of overall metal detecting community sizes for any analysis, but rather relying on like data. Hardy, however, disregards that second element that is crucial for our methodology to work as well: he does not limit his comparison to membership figures of the same type of social media – as we did with restricting ourselves to discussion boards only – but

[2] If X = A*F and Y = B*F, then A : B = (A*F) : (B*F) = X : Y; e.g. A : B = (A*0.5) : (B*0.5) = (A*0.3) : (B*0.3) = [A*2] : [B*2], etc. As long as **F** is a constant, it does not matter what the actual values of F, X, and Y are: as long as we have values for A = (X/F) and B = (Y/F), we can reliably establish the ratio between X and Y.

also liberally uses other kinds of social media data in some of his analysis, like the membership numbers of Facebook groups (e.g. "Metal Detecting Australia", Hardy 2017, 10, 46).

In fact, as will be shown in greater detail below (also see table 1), he doesn't even limit himself to social media group membership data only, but uses entirely different data, particularly for estimating numbers of active metal detectorists in England and Wales, and the USA (Hardy 2017, 15-17, 20-22). That any of the data he uses to establish his estimates for these countries were comparable like for like with any of the social media data used in his study is not even imaginable, let alone a 'reasonable' assumption.

As such, unless Hardy meant that using Google searches for finding data on the internet on numbers of metal detectorists in different countries is the *"novel method of open-source analyisis"* he is following, whose development he attributes to Möller and I, he has not followed our method at all. Rather, he has utterly misunderstood and perverted our method.

This is already highly problematic in itself, because we (Karl & Möller 2016; see also "An empirical examination of metal detecting") designed and used our method for a very specific purpose: to empirically test the core prognosis which can be deduced from the theory of the preventative effect of restrictive regulation of metal detecting; that countries with restrictive regulation have fewer metal detectorists per capita than countries with more liberal or no regulation of metal detecting. In other words: we designed our method for deductive hypothesis-testing, that is, to evaluate whether a particular statement is demonstrably false or is being confirmed by the particular data analysed.

It thus cannot produce meaningful results if (mis-) used in the way that Hardy 'applied' it, that is, for abductive comparisons of 'estimates'. Using it for the latter does not produce an empirical examination of anything, but just produces empirical data, as any Google search does in that it turns up information existing on the internet (whether that information is true or false). Hardy, however, does not seem to understand that.

In short: **Hardy transnationally compares on different kinds of data, created using different methods**.

Hardy's methods of 'estimating' metal detectorist numbers

While he claims (Hardy 2017, 8) to proceed like we did in our study (Karl & Möller 2016), he in fact does not. Rather, what he does throughout is to create 'estimates' for the number of active metal detectorists in each of the countries he attempts to compare. He then compares those 'estimates', as well as basing all his further comparative calculations on them. In other words, his study is based on the very fundamental flaw Möller and I tried to avoid by developing our method: he transnationally compares 'estimates', but without actually ensuring that the numbers he compares are actually transnationally comparable.

He does not even compare 'estimates' that have been arrived using the same kind of data and the same methodology. Rather, he compares 'estimates' which seem 'reasonable' to him, based on entirely different sets of data; data which, on top of everything, has been manipulated differently by him for different countries. Table 1 below gives an overview of the data used, and how it has been manipulated. It also shows the different percentages by which he has either in- or deflated data from different countries.

Australia	Illicit	Membership of largest MD Facebook Group recorded by Hardy himself	5,480	12/10/2016
deflated	6.85%	Poll by 'Marc' (2004)	**5,119**	Restrictive

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Austria	Illicit	Membership of largest online MD discussion board recorded by Karl and Möller	2,238	02/03/2015
deflated	6.58%	Poll by 'Marc' (2004)	**2,091**	Restrictive
Belgium	Licit	Licensed detectorists in Flanders according to President of the Bretagne Detection Association, Asterix	300	Sometime in 2015
unchanged			300	
	Illicit	Membership of largest online MD discussion board in Flanders recorded by Hardy himself	2,098	13/10/2016
deflated	19.92%	Poll by 'Marc' (2004), assuming 100% overlap between board membership, licit detectorists and members of other Belgian MD networks and no MDs in any other part of Belgium than Flanders	1,680	
deflated	5,63%	Sum total	**1,980**	Restrictive
Canada	Illicit	Membership of largest online MD discussion board recorded by Hardy himself	6,961	14/10/2016
deflated	6.58%	Poll by 'Marc' (2004)	**6,503**	Restrictive
Denmark	Licit	Based on report by Dobat based on official reporting figures for danefæ	202	2011
inflated	685.64%	Based on different numbers for danefæ and adding MD club membership based on figures provided orally by a Danish MD and reported by Dobat	1,385	
	Illicit	Membership of online forums recorded by Dobat and Jensen 2016	2,777	11/10/2016
deflated	56.46%	Poll by 'Marc (2004) and deducting 'licit' MD estimate from resulting figure	1,209	
deflated	6.58%	Sum total	**2,594**	Liberal
England and Wales	Licit	Estimated membership of NCMD as reported by Bailie & Ferguson 2017, modified downwards by removing the 313 Scottish members	14,687	12/2015 to 3/2016
inflated	66.11%	Based on surveys c. 2010 of commercial MD rallies in England identifying 39.8% of all participants were 'unaffiliated' reported by Thomas 2012	24,397	
	Illicit	Report by farmer John Browning from Suffolk that he had caught 50 'nighthawks' in 'the years preceeding' Oxford Archaeology's 2009 'Nighthawking' report	50	presumably before 2009
inflated	7,000%	Based on the assumption that all 50 'nighthawks' caught by John Browning were from the county of Suffolk, scaled up to national level	3,500	
inflated	89.94%	Sum total	**27,897**	Liberal
Ireland	Illicit	Membership of largest MD Facebook Group recorded by Hardy himself	1,207	11/10/2016
deflated	6.58%	Poll by 'Marc' (2004)	**1,128**	Restrictive
Netherlands	Licit	Membership of largest online MD discussion board recorded by Hardy himself	5,730	15/10/2016
deflated	6.58%	Poll by 'Marc' (2004)	**5,353**	Liberal since 7/2016
New Zealand	Illicit	Membership of largest relic hunter FB group recorded by Hardy himself but disregarding much larger group which also has gold prospectors as members with 2260 members	373	12/10/2016
deflated	6.58%	Poll by 'Marc' (2004), though if using the largest online group identified, the deflation would be by 84.69%	**348**	Restrictive

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Northern Ireland	Illicit	Membership of largest MD Facebook Group recorded by Hardy himself	241	11/10/2016
deflated	6.58%	Poll by 'Marc' (2004)	**225**	Restrictive
Scotland	Licit	Membership of a larger MD discussion board recorded by Hardy himself, but excluding the largest with c. 2,024 members, but a high percentage of non-Scottish residents as members, as being 'usual' in Scotland	1,549	11/10/2016
deflated	6.58%	2004 poll by 'Marc' (despite there being a poll on the very board used that shows up to 20.83% inactivity)	**1,447**	Liberal
USA	Licit	Estimate based on annual sales figures of 500,000 metal detectors reported at unspecified date and cited by Yoffe 2009 and annual consumption of 0.32 detectors per MD per year	160,000	presumably before 2009
miscalculated		Correctly calculated: **1,562,500** metal detectorists	**160,000**	Liberal

Table legend

Country	Licit or illicit MDs considered	Source for baseline data	Value of baseline data	Census date for baseline data
Data inflated or deflated	Magnitude of in- or deflation	Source used for in- or deflation	**Final 'low' estimate given**	System liberal or restrictive

Table 1: Comparison table of methods, data source, value and census date, data inflation or deflation, magnitude of data in- or deflation, source for factor used for in- or deflation, final 'low' estimate given and liberality or restrictiveness of national system used by Hardy (2017). Countries with restrictive systems shown with grey background, those with liberal systems with yellow background, the Netherlands with no colour due to recent change in this characteristic from restrictive to liberal. Figures deflated from baseline data shown in green, unchanged from baseline data in black, inflated from baseline data in red.

The 'other' countries

For the 10 countries other than England and Wales, and the USA, that he examines, Hardy (2017, 10-20) proceeds in a reasonably similar fashion, one that is reminiscent of the way we (Karl & Möller 2016) proceeded in ours, even if with some twists.

For those 10 countries, he uses as his baseline data the membership figure of the respectively largest (2nd largest for Scotland, see Hardy 2017, 19-20 for the rationale for this) social media group – whether that is a discussion board or Facebook group – he managed to identify by internet searches. The number so determined, he then reduces by 6.58% based on a poll undertaken by a user with the screenname of 'Marc' (2004) on the largest American 'treasure hunting' discussion board (http://www.treasurenet.com/forums/forum.php). This is based on Hardy's assumption that an equal percentage of users of metal detector discussion boards and Facebook group are inactive, despite the fact that a poll on the Scottish board he takes his baseline data from for Scotland indicated a 20.83% rate of 'metal detecting inactive' members. For some countries, that is, Belgium and Denmark, he then deducts from that the reported numbers of 'licit' metal detectorists, to be able to also create an 'estimate' of the number of 'illicit' detectorists (which is important for his later calculations of 'damage' done by those two different groups).

Still, the overall estimate for each of these 10 countries is his baseline figure, derived from the membership numbers of an online board or Facebook group, reduced by 6.58%. This is what he calls a 'low estimate' for these countries, disregarding in its entirety not just the possibility, but indeed the likelihood, that there may indeed be a considerable number of metal detectorists which are active in these countries, but have not subscribed to the respectively largest social media group for it. I will return to this point further below.

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In fact, based on his own argument, it is not just a 'low', but the minimum 'estimate' of how many metal detectorists must be active in each of these countries: it is the number of people who have subscribed to the largest social media group on this subject in each respective country, minus those who have to be assumed to be 'inactive'. Since this leaves only such that have to be presumed to be active metal detectorists, this gives a **minimum number of metal detectorists who must be presumed to be active** in each respective country.

Another kettle of fish: making up numbers for England and Wales

For England and Wales, he proceeds entirely differently to arrive at his 'estimate' of the number of active metal detectorists in these two countries (which he treats as one unit of assessment for the purpose of his comparison).

Here, he first 'estimates' the numbers of 'licit' metal detectorists. As the baseline data for his 'estimate' of the number of 'licit' detectorists, he uses the already estimated figure of c. 15,000 members of the National Council for Metal Detecting (NCMD) given by Bailie and Ferguson (2017, 14) for the whole of Britain, and reduces this by the 313 reported in the same source as 'Scottish' members of NCMD. Leaving aside for the time being that this is based on entirely different kind of data than he uses for the 'other' 10 countries; and assuming that all NCMD members (who, after all, pay a membership fee) are indeed active metal detectorists; the resulting figure of 14,687 would be the **minimum number of metal detectorists who must be presumed to be active in England and Wales**.

Thus, arguably, this would be the figure that could be transnationally comparable to the figures he established for the 10 'other' countries; even though of course there is the issue that there is no guarantee whatsoever that the minimum numbers of metal detectorists who must be presumed to be active in all these countries are actually representing roughly the same percentage each of the actual number of metal detectorists who are, and thus even a transnational comparison of these minimum numbers would be seriously methodically flawed. But at least, it would be comparing 'minimum estimates' with 'minimum estimates' across all compared countries.

Yet, that figure is not the one Hardy (2017) then uses as the 'low estimate' of the number of metal detectorists active in England and Wales in his comparisons and further calculations. Rather, he inflates that 'minimum estimate' by another assumed 9,710 additional 'licit' metal detectorists, based on Thomas' (2012, 58-9) result that at commercial rallies, 39.8% of participants stated that they were not affiliated with 'metal detecting clubs'. Hardy here assumes that those participating in these rallies who are members of NCMD would have stated that they were members of a 'metal detecting club'. Yet, it is entirely unclear as to whether the NCMD can be, and indeed would be considered by its members, a metal detecting 'club'. Indeed, NCMD both has members in and not in NCMD-internal 'clubs' (https://www.ncmd.co.uk/membership/uk/, 12/5/2017), implying that at least some of these would not consider themselves to be affiliated with a 'club' just because they are NCMD members.

At any rate, the figure of now 24,397 that Hardy uses from then onwards as his 'low estimate' for the number of 'licit' metal detectorists in England and Wales is inflated by c. 78% (accounting for the c. 66% by which the estimated membership of the NCMD is inflated, and the 6.58% by which the 'low estimates' for all other 10 countries have been deflated) compared to the figures he uses for the 10 'other' countries.

Yet, Hardy doesn't stop there. Rather, he proceeds to separately 'estimate' the number of 'illicit' detectorists, by first referring to the fact that a farmer in Suffolk claims to have caught *'about 50'* (Gooderham 2009) 'nighthawks' on his property over the course of several years (Hardy 2017, 16), even though in 2008, it only seems to have been three (Gooderham 2009). The source – and he

specifically stresses that he only used *'demonstrably reliable sources'* (Hardy 2017, 10) – for this is the vague recollection of that farmer, reported in the *East Anglian Daily Times*. This number of 50, Hardy then scales up to a nation-wide 'estimate' based on little more than the assumption that while these 50 probably weren't all from Suffolk, not every 'illicit' detectorist in Suffolk would have been caught by this farmer or even only detected on his land, and thus the 50 could simply be multiplied by 70 (for the remaining 48 counties of England and 22 of Wales), to arrive at an 'estimated' number of 3.500 'illicit' metal detectorists active in England and Wales (Hardy 2017, 17).

These he then adds to the 'estimated' 24,397 'licit' ones, since, despite there being a proven overlap between 'licit' and 'illicit' metal detectorists; which Hardy discounts for the reason that *'if this overlap was complete, it would suggest that 14.35% of detecting hobbyists were detector-using criminals'* (Hardy 2017, 17), and since his *'study's estimate for the number of licit detectorists is compatible with cultural property protection officials' as well as metal detectorists'* (Hardy 2017, 17), making it appear *'reasonable'* (Hardy 2017,17) to him. Thus, he simply adds his 'estimates' for the number of 'licit' and 'illicit' detectorists active in England and Wales up to arrive at his overall 'low estimate' for England and Wales. Thus, in Hardy's methodology, if one is a member of NCMD or an unaffiliated metal detectorist participating in detecting rallies, one cannot also be a 'nighthawk'.

Hardy's final 'low estimate' of 27,897 metal detectorists active in England and Wales thus is certainly not a 'minimum estimate' like those for the 'other' 10 countries he then transnationally compares it to. Rather, this 'estimate' is one of the **actual numbers of metal detectorists** Hardy believes to be active in England and Wales.

Compared to the 'minimum estimates' for the 10 'other' countries, this 'actual estimate' is inflated by a full 103.32% (if accounting for both the 89.93% inflation of the English and Welsh baseline figure and the 6.58% deflation of all others), or slightly more than double. Given this manipulation of the figures he then 'transnationally compares', it is hardly surprising that England and Wales comes up second in Hardy's (2017, 23) per capita 'league table', and first in his per square kilometre 'league table', of active metal detectorists.

A short digression: the percentage of metal detectorists subscribing to discussion boards

Interestingly, Hardy (2017, 15) almost completely disregards that our study (Karl & Möller 2016, 217) had found that on 2/3/2015, the largest UK metal detecting discussion board only had had 7,331 members, a number that has since (as of 11/3/2018) risen to 9,059.

Using the reasonably current figure, this would, using the same transformations as Hardy (2017, 10-20) applied to the comparable data he used for the 'other' 10 countries, give a transnationally comparable figure (that is, a figure arrived by subjecting the same kind of data to the same methodology across all compared countries) of only c. 8,463 active metal detectorists in England and Wales who had subscribed to the largest UK metal detecting forum. That figure, assuming Hardy's 'estimate' of c. 27,897 is a correct estimation of their actual number, would mean that only c. 30% of all active metal detectorists in England and Wales would be subscribers of the largest UK discussion board.

This is, of course, not just perfectly possible, but quite likely: it must be assumed that not every active metal detectorist subscribes to an online discussion board for metal detecting. Also, a significant segment of those who have will not have subscribed to the largest one. There are, after all, several such boards of varied sizes active in the UK (see Karl & Möller 2016, 217 for an overview of all boards and their membership figures as of 2/3/2015), and thus, invariably, there will be some who subscribed only to a smaller one. Thus, it would seem exceptionally unlikely that any of the largest 'national' metal

detecting discussion boards would represent 100% of the community of active metal detectorists in any country. Rather, any social media group membership must be assumed to represent at best a fraction of the overall number of metal detectorists active in the country the respective group serves. In fact, the English and Welsh figures collected by Hardy (2017, 15-6) prove as much.

One indeed must assume, as Hardy does, that there are likely at least as many active metal detectorists in the UK as NCMD has members. After all, NCMD members pay a membership fee, and it seems rather unlikely that many individuals who are not active metal detectorists would do so, since they would gain hardly any benefits from their membership. Thus, taking the figure of c. 15,000 reported by Bailie and Ferguson (2017, 14) to be correct, there must indeed be at least the c. 14,687 active metal detectorists in England and Wales that Hardy (2017, 16) calculates. Yet, the largest metal detecting board in the UK has c. 5,628 fewer members than that; members which hail from all over the UK, and not just England and Wales. Thus, even if one were to disregard Hardy's 'estimate' of c. 27,897 active metal detectorists in England and Wales completely, and just go with the plain NCMD membership figure, the largest board still does not represent 100% of all active metal detectorists, but just a fraction of their overall number.

Thus, Hardy should have realised that, if in England and Wales, the number of subscribers to the largest 'national' metal detecting discussion board was only about one third of the 'estimated' overall number of active metal detectorists in these countries, the same or at least something very similar would also apply in all other countries: that the largest 'national' board would not represent anything near 100% of the community of active metal detectorists, but only some fraction of it.

That, however, rules out the 'transnational comparison' Hardy (2017, 10-23) attempts between the 10 'other' countries for which his 'low estimates' are based on board and social media group membership, and his 'estimates' for England and Wales. After all, for the 10 'other' countries, Hardy (2017, 10-20) takes the membership figure of the respectively largest 'national' board or social media group to represent c. 107% of the number of metal detectorists active in each of these countries. For England and Wales, on the other hand, he knows that if his 'estimate' of active metal detectorists were correct, the membership figure of the largest English and Welsh board would represent only about a third (or indeed, using the figure of 6,250 he gathered by working with the data we had collected on 2/3/2015, only c. 22.5%) of his 'estimated' number of active metal detectorists in England and Wales (see Hardy 2017, 15).

This constitutes a major and insurmountable problem for a transnational comparison of these figures. As outlined above, what Hardy is trying to do is to transnationally compare the numbers of metal detectorists active in each of the compared countries, with the ultimate goal to establish whether more liberal or more restrictive regulation of metal detecting is more effective to reduce damage done by this activity to the archaeological record. Thus, what Hardy is doing is trying to establish the ratio between unknown figures, X (the actual number of metal detectorists in country 1) and Y (the actual number of metal detectorists in country 2). He knows other figures, A (e.g. the number of social media or metal detecting association members in country 1), and B (e.g. the number of social media or metal detecting association members in country 2). He also knows that A is a fraction F_1 of X; and that B is a fraction F_2 of Y. He thus is working for his 'transnational comparison' with the mathematical formula:

$$X : Y = (A/F_1) : (B/F_2)$$

The problem is: this formula can only create a correct result if both F_1 and F_2 are positively known, or if $F_1=F_2$, that is, indeed, F is a constant, as already explained in footnote 1 about the same formula used by Katharina Möller and I for the same kind of transnational comparison (Karl & Möller 2016).

And indeed, Hardy assumes that F is a constant for all 10 'other' countries in his comparison: he assumes that, regularly across those 10 countries, 93.42% of the members of the respectively largest social media group he has found in each country are active metal detectorists. Thus, he sets X = (A*0.9342).

However, where Y is concerned, that is, England and Wales, he does not establish this by setting it Y = (B*0.9342), but rather 'estimates' a value for Y using different methods that equals 455% of B. So Y = (B*4.55). That, however, would mean that F is not a constant, but rather a variable that can vary at least by a factor of c. 5 (455/93.42=4.87), that is, almost half an order of magnitude.

But if F is not a constant, but differs from country to country, then Hardy cannot set it as a constant for the 'other' 10 countries either, especially not as his F_1 isn't even derived from data from any of these 10 countries, but indeed based on data from a 12th country. As F_1, he sets the value of 93.42% he established based on the poll by 'Marc' (2004), conducted on the largest metal detecting board in the USA.

To make matters worse for Hardy's attempt at a 'transnational comparison', the 'estimate' he arrives at for the USA (Hardy 2017, 21-2) also proves that the value of 93.42% must not be used as a constant that can be applied to deflate board membership numbers to arrive at 'low estimates' in the 10 'other' countries. Hardy (2017, 20-2) gives as his 'low estimate' for the USA a figure of c. 160,000 active metal detectorists. Yet, the board from which the poll by 'Marc' (2004) was taken, which is the largest of its kind in the USA, as of 2/4/2017, only had 113,967 members. If one discounts the 6.58% of 'metal detecting-inactive' members of this board (based on 'Marc' 2004), this leaves us with 106,468 members of this board who we can presume to be active metal detectorists. But this is just 66.54% of Hardy's 'low estimate' for the USA. Again, assuming Hardy believes his 'estimate' for the USA to be correct, this proves positively that while only 93.42% of the members of the largest metal detecting discussion board in the USA may be active metal detectorists, the membership of that board only represents about two thirds of the active metal detectorists in the USA.

What makes matters even worse, Hardy has miscalculated his figure of metal detectorists active in the USA: while he 'estimates' 160.000, based on his explanations as to how he arrives at this 'estimate', the actually correctly calculated figure of presumably active metal detectorists in the USA would be 1.5625 Million (more on that little nugget below). Thus, the membership of the largest discussion board in the USA would only represent c. 7% of all metal detectorists presumably active in this country.

Either way, Hardy would have had to have known that, if his data and 'estimates' for England and Wales, and the USA, were correct, the number of members of the largest 'national' discussion board would be utterly useless for any transnational comparisons: that membership figure could represent anything between c. 125% of all active metal detectorists in any country, and as little as 7% of them, a difference of over one order of magnitude.

If put into the transnational comparison formula, this would not allow to deduce the ratio between X and Y by establishing the ratio between A and B. After all, X could be any fraction F_1 of A, and Y any fraction F_2 of B, with us not knowing what values fractions F_1 and F_2 actually have. Thus, Hardy's equation ends up as one with two unknown variables too many, as:

$$?^X : ?^Y = (A/?^{F_1}) : (B/?^{F_2})$$

This, however, is a meaningless equation, and thus also a meaningless comparison. Establishing a ratio between e.g. a figure A = 10 and a figure B = 20, to draw conclusions about the ratio between two unknown figures X and Y that A and B represent, is meaningless if we do not know what fraction of X

A represents, and what fraction of Y B. That the ratio between A and B is 1:2 does not tell us that the ratio between X and Y is actually 5:2, because A represents only 10% of X while B is 50% of Y. Or that the ratio between X and Y is actually 1:20, because A represents 100% of X but B only 10% of Y. If the ratio between A and B does not tell us anything meaningful about the ratio between X and Y, then there is no point in comparing A and B at all.

Thus, Hardy's transnational comparison either is utterly pointless to start with, since he compares unknown fractions of unknown numbers with other unknown fractions of other unknown numbers, or is fundamentally false. If the membership data taken from discussion boards cannot be compared directly, it cannot be used for transnational comparisons in the way Hardy does either. If it can be transnationally compared, it can only be compared directly and must not be manipulated as Hardy does. There simply is no middle ground where some data can be manipulated one and other manipulated another way and the result arrived at still be considered reliable.

More of Hardy's 'estimation' methods: miscalculating figures for the USA

But let us now return to how Hardy did calculate his 'low estimate' for the 12th and final country in his comparison, the USA (Hardy 2017, 20-2), because he yet again uses completely different kinds of data and an entirely different methodology for this than for any other of the transnationally compared countries.

Instead of relying on any internet discussion board, social media or metal detecting association membership figure to arrive at a baseline figure from which to proceed, Hardy instead relies on 'data' about metal detector sales figures. According to yet another one of his apparently *'reliable'* (Hardy 2017,22) sources, Emily Yoffe, a journalist, *'Debra Barton of First Texas Products, manufacturer of my Tracker IV, estimates the handful of domestic producers sell a half-million a year'* (Yoffe 2009). Leaving aside that I do not consider such second-hand hearsay reports by ever so slightly partisan journalists of 'estimates' by sales reps to be reliable evidence; and leaving aside that this second-hand source doesn't even say whether these are domestic or global sales; this provides Hardy (2017, 22) with his baseline figure for the USA of 500,000 metal detectors sold per annum, which he takes it to – exclusively – be domestic sales.

He then multiplies this baseline figure of 500,000 with an *'established estimate of the consumption of 0.32 detectors per detectorist per year*' (Hardy 2017, 22), an estimate which seems to have been 'established' by his own research. I will accept this estimated rate of consumption as correct for the sake of this argument. Thus, he arrives at his 'low' estimate of c. 160.000 metal detectorists in the USA.

Of course, once again, this figure is not an estimate of the minimum number of metal detectorists which must be presumed to be active in the USA, but rather of the **actual number of metal detectorists** thought likely by Hardy to be active in the USA. Thus, again, for this reason alone, it is not meaningfully transnationally comparable to the 'minimum estimates' Hardy created for the 10 'other' countries. But that, in this case, is almost a minor issue compared to the shocking mathematical mistake made by Hardy when calculating it.

To repeat: he **multiplies** the reported **annual sales figures** of metal detectors with the **annualised consumption rate of 0.32** detectors per detectorist (Hardy 2017, 22). Yet, an annual consumption rate of 0.32 detectors per detectorist means that every detectorist on average buys a new detector every 3.125 years.

Thus, Hardy would have had to divide the annual sales figures with the annual rate of consumption of detectors; rather than multiply it: one would only arrive at c. 160,000 active detectorists in the USA

based on 500,000 annually sold detectors if every detectorist on average would buy 3.125 new detectors per year, not only 0.32. Thus, if calculated arithmetically correctly, the figures presented by Hardy (2017, 22) would require him to 'estimate' the number of active metal detectorists in the USA at **1.5625 Million**.

Now, this is quite interesting, because if one looks at Hardy's per capita league table of the 12 countries he 'compares' transnationally, the USA already come first based on his 'low estimate' of c. 160,000, with 1 metal detectorist per 1,917 inhabitants (Hardy 2017, 23). England and Wales, who come 2nd in this table, already have 8% fewer metal detectorists per capita than the USA, if one were to believe Hardy's figures.

Yet, if one used the correctly calculated 'low estimate' of 1.5625 Million instead, the per capita figure for the USA would come down to as many as 1 active metal detectorist per c. 196 inhabitants. Even England and Wales, with its excessively liberal system and the PAS which even advertises metal detecting to the public as something positive rather than reprehensible, would have a whopping 10.5 times fewer active metal detectorists per capita than the USA. Even more remarkably, the USA would also move up to 2nd place in the per square kilometre league table that Hardy (2017, 24) also has kindly provided, with 1 metal detectorist per pretty much exactly 6 km^2. As a country with a population density of 32.73 inhabitants per km^2, it would sit just slightly below England and Wales, with a population density of 382.99 inhabitants per km^2, and slightly above the Netherlands, with 407.69 inhabitants per km^2.

As a hobby, metal detecting would thus have to be immensely popular in the USA, 10 times more popular than in any other country in his comparison.

To put it rather bluntly, the figure Hardy (2017, 22) presents as his 'low estimate' for the number of metal detectorists in the USA is made up, plain and simple. It is a number which may have seemed 'reasonable' to Hardy, because it is somewhere in the middle of the 'estimates' by others he found somewhere or other during his web searches. What it isn't, however, is a reliable 'estimate', based on actual, reliable data. The basic arithmetic mistake in Hardy's (2017, 20-22) calculation of his 'estimate', of multiplying where he would have had to divide, just makes it more transparent than with most other estimates that his figures are not 'reliable' in any way, shape or form, but wild guesses.

Conclusions: Hardy's fundamental mistakes

To conclude, in this short discussion it has been demonstrated that Hardy's (2017) article is fundamentally methodically and arithmetically flawed.

He compares incomparable data with no regard to transnational data comparability whatsoever. For **Australia, Austria, Belgium, Canada, Denmark, the Republic of Ireland, the Netherlands, New Zealand, Northern Ireland, and Scotland**, he creates 'low estimates' which reflect the **minimum number of** people who must be assumed to be **active metal detectorists** in each of these countries. His 'estimate' in each case is established by slightly deflating the membership figure of the respectively largest (or 2nd largest in case of Scotland) national metal detecting discussion board or Facebook group.

These, then, he compares with allegedly also 'low' 'estimates' for England and Wales, and the USA. However, the 'estimates' for these countries are not those of the minimum numbers of metal detectorists who must be presumed to be active in them, but rather such of what Hardy believes to be 'reasonable' estimates of the **actual numbers of active metal detectorists** in these countries. Of those, the 'estimate' for England and Wales is based on the vastly inflated, estimated membership

figure of NCMD plus another inflated number for 'illicit' metal detectorists derived from scaling up an uncorroborated claim by a farmer in a local newspaper. This is even though Hardy could have used the plain number of NCMD members as a 'minimum estimate' of metal detectorists who must be presumed to be active in England and Wales, a figure which might (just about) have been transnationally comparable to those for the 'other' 10 countries at least to some extent. The 'estimate' for the USA, finally, is simply a made-up number that seemed 'reasonable' to Hardy, but that is actually based on a shocking arithmetic mistake which, if corrected, changes Hardy's 'estimate' by a full order of magnitude.

Of course, it is **methodologically inadmissible to compare minimum estimates** – that is, figures that represent the lower end of the scale of possible values of a quantity, in this case of metal detectorists – **for some countries with estimates of the actual number of metal detectorists** – that is, a number somewhere between the lower and the upper end of that scale of possible values of the same quantity – **in others**. Any conclusions drawn from any such comparison are necessarily fundamentally methodologically flawed and thus cannot be taken as a serious contribution to academic debate.

Thus, rather than having conducted a sound empirical study, based on a rigorous methodology, consistently applied to actually comparable data, **Hardy (2017) produced a transnational comparison of wild guesstimates that seemed 'reasonable' to him, but actually only show his bias**. Rather than telling us anything about whether restrictive or liberal systems of regulating metal detecting are more effective in reducing damage to archaeology, his study only tells us which way of regulating metal detecting Hardy prefers, whether consciously or subconsciously.

The method Hardy actually uses – which has no relation whatsoever to that used by Möller and I in our empirical examination of metal detecting regulation – is unsuited to answer the questions he asks; and his study is executed exceptionally badly, even at the level of basic arithmetics. The conclusions he arrives at, while clearly popular with some partisan factions in this debate (The Heritage Journal 2017) who share his bias, are, thus, not trustworthy at all. **Hardy's results and conclusions therefore must sadly be disregarded in their entirety**.

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