Explorative Nanophilosophy as *Tecnoscienza*

An Italian Perspective on the Role of Speculation in Nanoindustry

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Abstract: There are two primary camps in which nanotechnology today can be categorized: normal nanotechnology and speculative nanotechnology. The birth of nanotechnology proper was conceived through discourses of speculative nanotechnology. However, current nanotechnology research has detracted from its speculative promises in favour of more attainable material products. Nonetheless, normal nanotechnology has leveraged the popular support and consequential funding it needs to conduct research and development (R&D) as a result of popular conceptions of speculative nanotechnology and its promises. Similarly, the scholarly literature has shifted its focus away from speculative nanofutures towards normal nanotechnology R&D. This paper shows the incongruences between the representation of nanotechnology in the media, scholarly journals and industry.

Keywords: nanotechnology; atomically precise manufacturing; speculation; anticipation; nanoethics.

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1. Introduction

Manufacturing today is capable of some impressive high-precision techniques such as x-ray lithography for building electronics components. However, existing methods struggle to achieve atomically precise manufacturing (APM), which is the assembly of materials with atomic precision. In APM, materials are built atom-by-atom. This is one form of nano-

technology. The idea of APM dates to Richard Feynman's 1959 talk "There's Plenty of Room at the Bottom" and active APM research began with K. Eric Drexler's 1986 book *Engines of Creation*. Despite this rich history, APM today is crude, limited to a handful of select materials, and many in the field doubt that more advanced APM can ever be realized (Drexler et al. 2007). The debate about the feasibility of APM centers around its mechanical conception of atoms and molecules (Auffan et al. 2009; Snir 2008; Baumberg et al. 2007). In APM, individual atoms are put in place in a fashion analogous to the mechanical assembly of components in traditional macro-scale manufacturing. However, critics like Richard E. Smalley believe that this concept is fundamentally flawed (Baum 2003). They argue that it is impossible to create the physical bonds between atoms or molecules directly by mechanical means (Baum 2003). Instead, an additional physical or chemical agent is needed to create the bonds, as found throughout traditional chemistry. If the critics are right, then APM is no more than an interesting intellectual exercise with negligible scientific merit or practical application. However, if the critics are wrong – if advanced APM is indeed feasible – then the implications are enormous. Simply put, APM could enable unparalleled sophistication in manufacturing. Some APM proponents postulate that APM would usher in a revolution in manufacturing on par with the industrial revolution or the computer revolution. Drexler refers to this as "radical abundance" (Drexler 2013b). The sweeping vision includes no less than unparalleled solar cells to combat climate change, the abundance of medicines and foodstuffs to eradicate disease and poverty and the strict control of manufacturing by-products that will make harmful waste a remnant of the past. However, APM also has the potential to create an abundance of highly precise and effective weapons system and surveillance technologies (see also Altmann 2005; Drexler 2007; Joy 2000). APM thus falls into the same category as other high-stakes speculative future technologies like nuclear fusion power and artificial superintelligence. These technologies might not be possible or might never be achieved by human engineering. However, if they are achieved, they could fundamentally transform global human civilization. A counterargument – arguing against R&D – can be made on the grounds of cost-effectiveness. Developing these technologies can be very expensive. Funding bodies often hesitate to allocate scarce resources to projects with such uncertain payoff. Indeed, APM has historically struggled to attract investment, with nanotechnology funding going primarily to more low-risk, low-reward technologies. Fusion power and superintelligence have faced similar situations in the energy and AI sectors, respectively.

Regardless, although APM proper as an object of research has failed to secure direct research investment, other 'normal'[1] nanotechnologies such as nanomaterials have become a multi-billion-dollar industry (Harper 2011). The causes of these substantial investments can be accounted primarily by the merits of the technologies per se. However, the conten-

tion of this paper is to discuss the effects of technological speculation on early-stage nanotechnologies. In a word, this article seeks to determine the effects that speculative nanotechnology has and is having on normal nanotechnology research. To accomplish this task, this paper situates itself by limiting its scope to the Italian nanotechnology industry. Because nanotechnology R&D is relatively young in the Italian sovereign in comparison to the United States and the United Kingdom, Italy provides this paper with a nesting ground in which policy and governance recommendations have the best opportunity to inform the responsible innovation of nanotechnology.

2. Methodology

This paper takes a wholly unorthodox approach to the investigation of the effects of speculation on current research trends. Existing nanotechnology literature has traditionally focused on nanotechnology funding (Roco 2005; Harper 2011), the feasibility of advanced nanotechnologies (Drexler 2006, 1986; Phoenix and Drexler 2004; Freitas 2016; Freitas and Merkle 2004; Jones 2005), its potential future applications (Freitas 2015, 2010, 1999; Boenink 2010; Moscatelli 2013; Vandermolen 2006), as well as its risks and governance (Boenink 2009; Wejnert 2003; Cowper 2006; Vandermolen 2006; Phoenix and Drexler 2004; Moscatelli 2013; Pelley and Saner 2009; Roco 2008). As such, this paper provides a novel analysis by looking specifically at the exponentially growing Italian nanoindustry and showing that a strong correlation exists between the media/scholarly speculation and anticipation of nanofutures and the current 'normal' nanotechnology ventures[2]. This paper does not intend to replicate existing research literature on funding or policy in coming to its conclusions if any, but instead, provide both a media and literature analysis of how nanotechnology is represented in the media and elite scholarly journals. As such, although Italy and its nanoindustry will comprise the centre of this investigation, broader global implications for research and speculation will necessarily come into play. The preliminary conclusions of this paper show that the funding and current nanotechnology research has, at the very least, been spurred by the springboard of speculative nanofutures. However, there is a 'severing' both in the media and the scholarly literature. This paper will show that the media often represents and mediates humbler 'normal' nanotechnology creations as speculative nanofutures. Whereas the discussions of nanotechnology in scholarly journals have shunned discussions of speculative nanofutures in favour of discourses surrounding these humbler pursuits. Thus, current nanotechnology ventures have profited dramatically from funding bodies and public acceptance as a result. This incongruence – this severing – provides an unrealistic account of what is occurring in nanoindustry, how speculation and ongoing research co-construct one another through a series of indi-

rect assemblages that are mediated, translated and eventually represented by the media and scholarly research. Because the thesis of this paper dramatically hinges on media stories that cite nanotechnology, the identification of such stories in the Italian sphere is of primary importance. To do this, this article is heavily based of the conclusions drawn Arnaldi (2014) in retrieving Italian news stories, reports, and interviews that feature nanotechnology and notable Italian nanoscientists ranging from 01 January 2001 to 31 March 2012. His report used a complex Boolean search string to retrieve news stories. This work, based on that of Dudo et al. (2011), has the benefit of reducing false positives and only presenting tangential search results thus decreasing the screening work needed (Arnaldi 2014; Dudo, Dunwoody, and Scheufele 2011). Going one step further, this paper uses the work of Arnaldi (2014) as an implicatory index for that date range. As such, because the contention of this article is to unearth the division between media and academic discussions of nanotechnology, and given that the debate on speculative nanoethics, which partially took place in the journal Nanoethics[3], took place roughly between 2007 and 2010, the work by Arnaldi (2014) is only partially sufficient for this paper. What is needed is both the work drawn from his article as well as media and academic coverage of nanotechnology that proceeded it. Thus, this paper builds on this previous work by revaluating the narratives from that period as well as news stories from 2012-2017 (inclusive). Like the mentioned study, three major Italian daily newspapers have been selected to provide the sample of nanotechnology media coverage (Corriere della Sera, Il Sole 24 Ore, La Stampa).[4] To accomplish this, the three daily newspapers have been searched using the online search engine Factiva for pertinent articles containing the keywords 'nanotechnology', 'molecular manufacturing,' 'atomically precise manufacturing' and 'nanoscience.[5] The search was run for news stories from 1 April 2012 to 31 December 2017.[6] The starting date was chosen as it directly follows from Arnaldi (2014)'s last search date selected, thus providing a smooth continuity of news coverage that could be relevant to the present study. News stories were then screened for at least one present complete phrase pertinent to nanotechnology, anything less provided insufficient information, including classifieds, obituaries or other directly irrelevant results. A total of N = 55 items were retrieved from the database, notably less than the 218 items retrieved by Arnaldi during the 2001 – 2012 range. Additionally, replicating the Arnaldi Boolean search string, this time with the addition of the search terms for 'molecular manufacturing' and 'atomically precise manufacturing', the original 2001- 2012 search span resulted in a new total of N = 224 items (6 more which specifically mention the future nanotechnology pertinent to this paper's thesis. Similarly, of the N = 55 items from the 2012 – 2017 search range, a total of N = 0 items mention any of the future nanotechnology search terms even once.[7] The following section will introduce the theoretical groundwork and literature that has focused on the implications of speculations on the

development of emerging technologies and how such discourses can be used with this particular case study.

3. The Role of Speculation in Contemporary Development

Speculation also termed anticipation (particularly within the diverse technoscientific discourses) has played a critical role in the development of nanotechnology since its inception. These speculative narratives have had severe material consequences, the most significant of which has led to the suppression of speculative nanotechnology narratives in most nanotechnology discourses (see Michelfelder 2011; Grunwald 2010; Nordmann 2007; Nordmann and Rip 2009), however, there has also been some pushback by scholars, proposing that speculation, aside from having real effects over contemporary technological developments, in itself has utility in the scientific and governance discourses (Roache 2008; see also Selin 2007). The severing is multifaceted, and this paper aims to unearth some of these incongruences. Similar to the scholarly discourses that have their own debates on the value of speculative nanophilosophy, the risk assessments of both current nanotechnology ventures and potential nanotechnology applications and future developments have a severing of their own. The scope and context of risk assessments with nanotechnology differ between expert and public evaluation (Tyshenko 2014; Hinds 1999). Expert evaluation of risk tends to focus more heavily on a limited scope of potential risk-outcomes such as expected loss, death or grave injury whereas public assessments tend to be less formalized and broader (Hinds 1999). The public perception of risk as such has become the subject of further study given its material impacts on the development of emerging technologies (Lee et al. 2005; Lemyre et al. 2006). Not only this, but efforts to deconstruct the causes for public rejection of specific emerging technologies genetically modified organisms and nuclear energy production (Gupta, Fischer, and Frewer 2012). Several of these research reports that focus on public perceptions of nanotechnology have been published (Cobb and Macoubrie 2004; Priest 2006; Siegrist et al. 2007). Although these surveys are over a decade old, they continue to provide novel insights on the discrepancy between public and expert opinion of current and potential future applications of nano-technological systems and materials. The primary conclusion of these studies is an observation that despite decades of public funding and development of nanotechnology and its now widespread influence and interdependency with a large number of other industry and research domains, public attitudes, and understanding of nanotechnology remains limited and not well-informed. Initial conceptions of nanotechnologies were entirely dichotomous, either framed as utopian or dystopian in character. Discussions about the 'radical abundance' of energy, material wealth, and basic life necessities were envisioned with arguments that it would be this transformative technolo-

gy that would be the centre of the fourth industrial revolution (Curtis et al. 2006; Tyshenko 2010; Salamanca-Buentello et al. 2005; Drexler 2013b, 2013a). Catastrophic consequences to the development of the same technology were also projected, including environmental devastation, the erosion of any notions of privacy and the infamous 'grey goo' scenario (Joy 2000; Drexler 2006, 2013a). These radical future speculations were, over time, overwritten with more 'down to earth' framings that provided less extreme interpretations of nanotechnology benefits and risks and relegated the catastrophic and abundance characteristics unlikely probabilities (Dowling 2004). This characterized the first decade of 21st-century nanotechnology and nanoethics research; heaver focuses on more immediate nanotechnology innovations and a shift away from speculative nanofutures. As things currently stand, as of 2012, academic research that focuses specifically on speculative nanofutures had all but died out. Mentions of speculative nanotechnology in academic scholarship has been relegated to an ancillary role in demonstrating potential convergence characteristics of nano-bio-info-cogno (NBIC) technologies and risk research (i.e., Bostrom 2014; Torres 2017) or published privately outside traditional academic peer-reviewed platforms (i.e., Freitas 2015; Vassar and Freitas 2013; Freitas 2016; Lewis 2016).

However, persuasive arguments have been levied that it was the foundational character of earlier media and other popular works that spurred public investment and interest in what is now normal nanotechnology by showing particularly utopian speculative futures (Arnaldi 2014; Arnaldi and Tyshenko 2014; Drexler 1986, 2006). As such, the current global nanoindustry, particularly that of the United States and its federal National Nanotechnology Institute, have significantly profited from the public support for nanotechnology, even though the current nanotechnology research is far removed from the promises of molecular engineering and radical abundance that nano-optimists[8] have speculated (Drexler 2013b)[9].

4. Italy and Nanoindustry

As such, how do we situate all of these states in the context of the Italian nanotechnology industry? Despite Italian innovations and investments lagging significantly behind those of the US, Russia, China and other EU states, there is nonetheless a growing interest in nanotechnology research and increase in public funding (Istat 2013). There are several dimensions contributing to Italy's past and current position in nanotech innovation such as a small number of large firms that operate in sectors that are knowledgeable in nanotechnology, the restricted role that business play in research and development, the narrow use of public research on the actual industrial practice (even though Italian scientists have been lauded for their scientific achievements). These factors are not exhaustive, but all

play a role in the hindrance of the Italian contribution to nanotechnology innovation (Wired and Cotec 2009). Regarding the investments made on the peninsula, they are relatively low in comparison to other states.[10] Investitures are estimated at roughly 100 million euros annually; comprised both of Italian federal funding as well as EU funding. However, despite poor relative investments, the professional interest in nanotech has garners increased attention over the years, particularly between the years of 2004-2010 where the total number of private companies directly involved in nanotechnology increased from 20 to 85 percent. Additionally, the Third Italian Nanotechnology Census reported that as of 2010 there were 190 existent Italian research centres dedicated to nanotechnology and explicitly observed a growing interest in nanotechnology in Italian centres (Airi Nanotec 2011).

Nonetheless, problems are still persistent, primarily on account of the lack of private investments that other countries such as the United States possess as well as a unique severing between industry and relevant public research. Not only this, but a 2010 survey conducted by WIRED and COTEC reported that just 3.1% of the sample surveyed felt that they were 'well informed' of current nanotechnology with 72.8% reporting that they thought they were either poorly or not at all informed on the topic (Wired and Cotec 2010). Similarly, although research and development in the fields of nanotechnology in Italy continue, and more industry firms emerge, there is yet to exist a strategic government plan regarding nanotechnology in Italy, and as such, difficulties arise for citizens and researchers to learn about funding opportunities within the nation as well as statistics that clearly explicate the nation's actual state of development (Nanowerk 2013; Berger 2013). The third 'Census of Italian Nanotechnology' that was conducted by the firms AIRI/Nanotec IT and published in 2011 was the last of these official reports that gave an insight into the status of nanotechnology innovation in Italy. Coupling the information retrieved from the Factiva search regarding public dissemination of nanotechnology innovations as well as the current state of nanotechnology funding in Italy, we can begin to sketch some interesting correlative results.

5. Sketching the Severing

Firstly, there is a marked relationship between the quantity and character of the newspaper articles that talk about nanotechnology prior and post-2012. Prior to 2012, there are at least six articles that explicitly discuss future nanotechnology, with over 224 items that address nanotechnology more broadly. There is a marked drop after 2012 that correlates precisely with the definite shift in the research aims regarding nanotechnology. The scholarly debates that took place, more primarily in the jour-

nal Nanoethics, surrounded the value of speculative nanotechnology and dedicating resources to its dissemination (for specific articles on this debate see Roache 2008; Grunwald 2010; Nordmann 2007; Boenink 2009; Nordmann and Rip 2009). As such, there was no overtly expressed decision that concluded the debate, instead what resulted was a quite fizzling that ended with a near-universal moratorium on publishing purely speculative works on nanotechnology.[11] For this reason, there have been no marked works on purely speculative future nanotechnology in academic journals. However, it warrants mentioning that there do exist more recent scholarly book publications that explicitly discuss future nanotechnology, but never so in an exclusive or exhaustive capacity, but instead it is levied as an illustration of the effect of technological convergence and existential/catastrophic risk (Bostrom 2014; Torres 2017; see also Freitas 2016 who continues to self-publish articles on this topic at his Institute for Molecular Manufacturing).

As such, we can see how media outlets, in this case, Italy's three largest newspapers, has had a similar lack of publications on speculative nanofutures, that, at one point, help to construct the popular support that has enabled the base-level infrastructures to the now burgeoning Italian nanoindustry (as shown by those articles listed in Appendix B).

Another interesting correlation to note is not only is there a total lack of articles on speculative nanofutures in the search results post-2012, but there is a marked decrease in media coverage in general about broader nanotechnology. This severing can be attributed to multiple potential causes, none of which this paper aims to argue for. Such reasons can be: (1) a lack of academic research with future – nano-optimistic (i.e., revolutionary) – characteristics that the pre-2012 research possessed, (2) post-2012 literature no longer associates its research with its revolutionary origins, and (3) the very broad definition of what encompasses nanotechnology makes specific future applications nebulous (the latter is proposed by Drexler, 2013b). Regardless of which, if any, of the proposed reasons, are the cause of this severing is correct, one this is remarkably clear; the correlations between the academic moratorium on speculative research on nanotechnology is directly correlated with the lack of speculative media coverage on nanotechnology. The size of the Italian nanoindustry, because of its relatively small, yet growing, size makes this severing remarkably transparent, whereas the more extensive American nanoindustry and media outlets would make this Severing harder to discern.

6. Concluding Remarks and Further Research

By observing the coverage of both normal and speculative nanotechnologies in the Italian media, I have roughly discussed the relationship

between the academic discourses on nanotechnology and how that has co-constructed the media coverage of nanotechnology.

Firstly, the origins of nanotechnology, before material results in the field were produced, was purely speculative with either nano-optimistic or nano-pessimist anticipations. During this period of speculative nanofutures, the media played a critical role in the dissemination of these potential futures with similarly serious scholarly debate on the feasibility and ethics surrounding such technologies. This zeitgeist of speculative nanofutures began to pave the way for basic nanotechnology research that is argued to provide the fundamental building blocks for what was later to be called future nanotechnology such as the Drexlerian APM (O'Mathuna 2009; Drexler et al. 2007). New journals such as Nanoethics, with the aim to disseminate this new field of research and both public and private industry, centres Della for the R&D of nanotechnologies. Such institutions, like the NNI, profited much by the public support that was fostered by the news media in their speculative dissemination of humbler material developments (Tyshenko 2014).

However, a severing took place between 2007-2012, when academic research on nanotechnology became disinterested, and in some case, ideologically opposed to the dissemination of works of nano-speculation or anticipation, relegating them to a waste of research resources (Van Lente et al. 2012; Nordmann 2007, 2014). This is in specific opposition to works that argue that speculation on technologies provides an ideal initial exploration for the design and determination of values in directing potential futures (e.g., Alvial-Palavicino 2016; Foley, Bernstein, and Wiek 2016; Racine et al. 2014; Roache 2008). Thus, there are two severing at play, one that has emerged from within the academic discipline of nanotechnology research, one that is ideologically opposed to speculative works (the very types of works that founded and induced funding for the growing field) and another severing that is transdisciplinary; a severing between the merits of speculation/anticipation per se. The works produced through academic scholarship has genuine material consequences one what type of information gets disseminated, both academically and publicly. Similarly, can be said for the network of assemblages that the media influences as it relates to funding and support of academic research and ventures. Severings of this sort put a strain on what can and cannot be discussed in a sober and accountable fashion. As a result, questions of applied ethics come to the fore, particularly in being proactive for potentially transformative and disruptive technologies (e.g., NBIC technologies). Speculation, both in the media and in scholarship provide a means by which potential futures can be anticipated, and as a consequence, material steps can be envisioned to assess and direct desirable prospects. There is an extensive quantity of existing scholarship that disseminates the merits of proactive developments of transformative technologies instead of ex-post facto reactionary measures that often prove to be impotent (i.e., Davis and Nathan 2014, 2015; Roco 2011; Tait and Levidow

1992; van Wynsberghe 2013). To sum, this paper has taken up the specific case of speculative nanotechnology as a means to illustrate the relationship between the media coverage of nanotechnology and the academic scholarship on the topic. The Italian nanoindustry, because of its relatively small size and more recent birth, provides a novel, and unambiguous illustration for how the media coverage of nanotechnology changes before and after 2012, both in quantity and subject. Speculation on future technology, contrary to academic nanotechnologies, is not a fruitless endeavour. Similar research is currently being conducted in equally speculative fields of advanced artificial intelligence and biotechnology, and for a good reason (i.e., Armstrong, Bostrom, and Shulman 2016; Barrett and Baum 2017; S. D. Baum 2016; Etzioni and Etzioni 2016; Wiltshire 2015). Further research should seek to determine active ways to reinvigorate nanoethics, either in an ad hoc fashion or by informing a potential path from examples in the fields of speculative artificial intelligence research.

Appendix A: Boolean search term used to gather articles from the Factiva database

(atleast3 nanotechnologia OR atleast3 molecular manufacturing OR atleast3 atomically precise manufacturing OR atleast3 nanotecnologie OR atleast3 nanoscienza OR atleast3 produzione molecolare OR atleast3 produzione atomicamente precisa OR atleast3 nanorobot OR atleast3 nanobot OR atleast3 nanosci* OR atleast3 nanotec* OR assembla*/N2/molecolar* OR fabbrica*/N2/molecolar* OR atom* adj2 fabbric*) NOT (bomb/N10/atomic* OR arm*/N10/atomic* OR central*/N10/atomic* OR bomb*/N10/nuclear OR arm*/N10/nuclear OR nanosecond* OR apple OR ipod or mp3 OR digest OR notizi*/N2/brev*)

Appendix B: Complete list of articles from 2001 to 2012 that specifically mention future nanotechnology systems

Publication	Article Headline	Date of Publication
Corriere della Sera	La riparazione dell'elica	4 November 2007
Il Sole 24 Ore	I menù e il futuro saranno a base di pillole nutrienti	3 November 2006
Il Sole 24 Ore	Prospettive dell'invisibile	13 April 2006
Il Sole 24 Ore	Per il Centro ricerche Fiat più atturato anche fuori dall'auto.	24 January 2002
La Stampa	Addio chiavetta Usb C'è il filo intelligente. Anche l'Europa si lancia nel business delle microparticelle di pochi miliardesimi di metro	27 February 2008
La Stampa	Nano macchine	9 May 2001

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[1] Donal O'Mathuna (2009) coined the term "normal nanotechnology" in contrast to speculative or "future" nanotechnology. The term normal should not be confused with a Kuhnian 'normal' paradigmatic concept, but to refer to current or real developments in nanotechnology that are currently being developed or already ubiquitous. This is usually nanomaterials and nanosystems such as atomic force microscopy.

[2] Socio-technical assessments and evaluations such as this one can stem from various theoretical foundations. This paper provides a rudimentary empirical style approach as delimited in this section (S.2). Another mode of inquiry towards the sociology of expectations of socio-technical systems such as nanotechnology can take the form of sociotechnical imaginaries pioneers by Jasanoff and Kim (Jasanoff and Kim 2009, 2013; Jasanoff 2015; Jasanoff and Kim 2015). This is a principled methodology for determining the mapping of expectations and their real-world developments.

[3] The majority of the debate that took place in NanoEthics surrounded the value of conducting and publishing speculative works of ethics. Arguments against the speculative project mostly deferred to arguments about the opportunity cost of speculation that could have served more immediate interest (Grunwald 2010; Ferrari, Coenen, and Grunwald 2012; Nordmann 2007). On the other hand, arguments were made in support the value of speculative ethics in anticipatory rather than reactive governance strategies (Roache 2008; Swierstra et al. 2009; Rip 2007; Brey 2012)

[4] The Factiva search for all three news outlets encompassed both online and print databases.

[5] The terms chosen for the Factiva database search were used both in English and Italian to cover both of the possible language and nomenclature usages that are employed by the news sources. For a full list of terms and search, exceptions see Appendix A.

[6] Arnaldi (2014) explicitly excluded all search results by filtering out those that mention molecular manufacturing or nanorobotics. Given that these are fundamental concepts to speculative/future nanotechnologies, the original search date of 2001-2012 has been researched anew with the inclusion of these search terms in the Boolean string.

[7] See Appendix B for a list of articles from 2001-2012 that were collated that specifically mention future nanotechnology systems at least three times as per the Boolean search string conditions.

[8] The term 'nano-optimist' (as well as its opposite, nano-pessimist) was coined by (Arnall and Parr 2005).

[9] See Drexler, 2013b for a thorough discussion of how the NNI and similar institutions have arisen globally and have redefined what constitutes 'nanotechnology.' As such, the original promises of nanotechnology are very different from the current research that is globally being conducted.

[10] Whereas Italy spends roughly 100 million euros (as of 2010), The United States spends approximately 2-3 billion dollars publicly and an additional 4-5 billion dollars of private investment). Similarly, Japan spends nearly 1 billion dollars per annum, and Germany stands as the EU forefront in nanotechnology investment with a per annum approximant of 800 million dollars (Nanotec 2011; NSTC, COT, and NSET 2018).

[11] This is not only clearly visible in the lack of future nanotechnology literature post-2010, but it has also been clearly expressed to me by the editor of a top journal in the field and the cohort of reviewers who rejected a paper I had written purely because of its speculative nature. One reviewer regarded the article as being clearly something that is currently taboo, and more suitable to the pre-2012 discourses saying that "The submission reminds me of the early debate on nanotechnology more than 15 years ago. It is a reflection on the big issues of APM of which the idea goes back to science writer Eric Drexler (1986) and challenged by Bill Joy in 2000. My first impression was: the paper is about 15 years late. In the meantime, the nano-debate changed to a much more down to Earth mode, focusing, e.g., on ESH issues of nanoparticles while the more futuristic issues migrated to other fields such as human enhancement. Accordingly, my first feeling was: reject because the paper is out of time".