## ARTICLES FOR UTM SENATE MEMBERS

**“The Future of Higher Education”**

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Original research article

Colonising the future: Mega-trade deals, education services and global higher education markets

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A R T I C L E   I N F O

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Abstract

This paper explores a less well-examined aspect of time in relation to higher education and the academy; that of ‘time-future’. The paper takes the case of education trade strategies being pursued by governments and allied agencies, and explores the multiple ways in which time-future is mobilised. Drawing on trade documents, government statistics, and related reports, the paper points to two time-future dynamics at work. The first dynamic focuses on the ways in which the future is imagined by strategic actors, and legitimated through creating equivalences between education trade, economic growth and prosperity. The second dynamic explores the ways in which the current round of global and regional trade negotiations colonise the future as a political resource. I reflect on how time-future is a key resource and modality of power to be claimed and cognitively shaped so as to reorient actor’s expectations towards the rhythms and demands of capitalism, and away from the temporal orders of the academy. However, efforts to commodify higher education, on the one hand, and colonise higher education futures exclusively to serve the interests of economic investors, on the other, continues to be contested. As a result, a new temporal order is yet to become common-sense, and an existing order is yet to die.

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1. Introduction

A special issue given over to exploring the relationship between education, time and the future is an opportunity to think in more theoretically informed ways about this relation. To be sure, time features implicitly in the work of social scientists concerned with the social and political nature of education; for example, when they explore questions of social mobility, social reproduction, shifts in education governance over time, and so on. Education policy analysts also implicitly invoke time and the future in their examination of policies, most of which are aimed at bringing about some kind of change into the future. This state of affairs is not just an issue for social theorists of education. Helga Nowotny, in a seminal essay on time and social theory published in 1992, argues that whilst time has more recently featured as a context and theme of research into social life, theorising social time in a more substantive way has continued to lag behind. This is in part because, as Barbara Adam reminds us "... time is a deeply taken-for-granted aspect of social life".

Over the past two decades, there has been a growing engagement with time by social theorists, including the nature of social time in education sectors and settings. In Timewatch, Adam (1995) has a whole chapter on a range of education practices. She shows the ways in which, through the hidden curriculum, “... dominant temporal structures and norms of society are absorbed, maintained, re-created and changed in daily educational practice” (p. 59). Through clocks, timetables

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and schedules, children in western schools learn how long, in what order, and with what speed to work both now and into the future. Researchers of educational processes also use complex time orders, from time series data to trends and panel reports that in turn orient us socially and cognitively to the world in particular ways.

Much of the more recent work on social time in higher education explores the way in which time is mediated by neoliberal globalisation: for example, academic thought time is recast as money time (cf. Noonan, 2016); academic work is experienced by individuals as one of time shortages (cf. Vostal, 2015, 2016; Ylijoki & Mantyla, 2003); research time is experienced as a juxtaposition of different temporalities (Lapping, 2016). Yet aside from work on scenarios and other forms of horizon scanning (cf. Blass, Jasman & Shelley, 2010; Vincent Lancrin, 2004), the substantive theorising of time-future in higher education remains relatively under-developed, and particularly so in relation to questions of power, and of the future as a resource to be colonised.

My entry point in this paper will be the analysis of a case of the discursive recasting of higher education as a global trade in services sector. Drawing on trade documents and related reports, I point to two time-future dynamics. Firstly, I will focus on the diverse ways in which the future is imagined by strategic actors, and legitimated through creating equivalences between education trade and economic growth and prosperity. Secondly, I will show the way in which the current round of global and regional trade negotiations, such as the Trade in Services Agreement (TISA), the Trans-Pacific Partnership (TPP), Comprehensive Economic Trade Agreement (CETA) and the Transatlantic Trade and Investment Partnership (TTIP), all seek to colonise the future as a resource (Hagerstrand, 1985) through mechanisms such as progressive liberalisation/lock-in clauses so as to place these agreement off limits to democratic politics into the future.

Briefly, progressive liberalisation refers to the further extension and deepening of ‘free-market’ policies aimed at limiting state regulations. Lock-in clauses are used to place limits on governments putting a brake on, or reversing, liberalisation tendencies via increased state regulation. Future-time is thus a critical political resource to be captured, whilst individual actor’s orientations to this different market future needs to also be recalibrated so as to stabilise new meanings, practices and commonsense. These mega-trade agreements seek to transform the future into an extended present (Nowotny, 1994), whilst the extended present contains the progressive cognitive reorientation of actors to a future shaped by capitalist dynamics (Beckert, 2016). However, efforts to commodify higher education and colonise higher education futures exclusively to serve the interests of economic investors continue to be contested. As a result, a new temporal order is yet to become commonsense, and an existing order is yet to die. The structure of the paper is as follows. I begin with an account of efforts to reimagine higher education and its temporal order and how this in turn challenges the orientations of contemporary academics and institutionalised social practices. I then turn to a brief outline of the work of Jens Beckert (2016) and Helga Nowotny (1992, 1994, 2016) as resources to analyse the case of global higher education markets and trade and how their realisation within capitalist markets involves the cognitive reorientation of actors.

2. Higher education for a globalising world

There has recently been an explosion of education and futures work by governments and international organisations, including the Organisation for Economic Cooperation and Development (OECD), aimed at challenging and changing the ways in which teaching and learning in higher education is organised and delivered (see Vincent Lancrin, 2004). Such ‘futuring’ activities include the development of scenarios about current and future states of education, the promotion of foresight and horizon scanning activities aimed at managing both the risks that might impede the realisation of future states (Robertson & Muellerleile, 2016) and the risks of ignoring radical changes already taking place in the higher sector that could lead to catastrophic outcomes (Rizvi et al., 2013).

What these strategic interventions represent are explicit efforts to reshape higher education through imagining different kinds of challenges and futures for its institutions and subjects. Such efforts suggest not only distinct (and thus potentially competing) imaginaries and temporalities at work, but they in turn demand, and produce, particular kinds of cognitive orientations to time – as in time-past, time-present, and time-future. The classic metaphor of the Ivory Tower to describe the social-world of the university, with its enclosed spaces, quiet libraries and cloistered walkways, invokes the idea of time-space separate from the boisterous tempo of the outside world. In this world, academics are simultaneously tasked with the mantle of being guardians of accumulated past knowledge, whilst oriented to the present and the future by the diligent search for truth. In this socio-temporal order, blue skies research takes time, experiments can and do fail, and new knowledge is the happy outcome of serendipity. Uncertainties about the future are not as much uncertainties about bad investments or collapsing share prices (though as higher education becomes more and more wired into the global circuit of capital this is an inevitable outcome), but about what forms new knowledge might take, or even more prosaically, what my first-year class will be like this year! (Back, 2016)

Whilst clearly a caricature of the temporal order of higher education, and not all academics experience current changes as all bad, what the literature on time in the academy does agree on is that the pace of life and control over time in the academy has changed. Vostal (2015, 2016) shows not only that the structure of academic life and its temporal rhythms are being recalibrated but that these shifts can be linked to changes in the relationship between higher education and global capital. A shift away from one temporal order to another takes ideational, institutional and regulatory work, and the question of how we can understand this theoretically in relation to the social and political nature of time is the purpose of the following section.
3. The temporal orders of capitalism and its orientations

Any argument around higher education, the future, and the inclusion of education more directly in capital accumulation, suggests we need to look more closely at capitalism as a dynamic, and at its distinct temporal order. Here the work of Beckert (1996, 2014, 2016) and Nowotny (1992, 1994, 2016) are particularly useful for my purposes. In her recent book The Cunning of Uncertainty, Nowotny writes:

The arrow of time continues to advance the tenuous balance between the punctuated, incomplete and biased knowledge of the past and the uncertainty of what the future might bring. ...Ever since the modern societies manifested an unprecedented preference for generating novelty, the future became an open horizon with science and technology at the forefront, pushing further into the unknown (2016: vi).

Uncertainty is a powerful incentive in striving for more knowledge, and an inherent component of research within the academy (Nowotny, 2016: vi–xiii). And whilst capitalism itself is always seeking to manage the uncertainties surrounding the future, it is paradoxically also stimulated by innovation and feeds off of uncertainty, for instance through financial practices, such as hedge funds, risk assessments and insurance policies.

Jens Beckert has developed an impressive corpus of work on the temporal order of capitalism (cf. Beckert, 1996, 2014, 2016) that is particularly useful in that in developing a sociology of capitalism, he is particularly attentive to the temporal nature of social orders. Like others, Beckert (2014: 2–3) argues that both modernity and capitalism embrace distinctly different temporal orders in contrast to pre-modern and pre-capitalist orders.

Whilst pre-modern societies see themselves as living in a fixed, eternal present, by way of contrast modern societies tend to view the future as open and uncertain, or as a storehouse of possibilities. Yet as he also notes, much of the writing on temporalities and temporal orientations by sociologists has tended to focus on the development of modern societies and the political, rather than the economic. In speaking to this absence, he poses the question: “...how do perceptions of an open and uncertain future relate to the capitalist economy” (Beckert, 2014: 3)?

To answer his question, Beckert (2014: 3) turns to the work of the French sociologist, Pierre Bourdieu, and his accounts of the Kabyle people in French-controlled Algeria. Bourdieu was particularly interested in changes in temporal order within Kabylia as a result of capitalist modernization in Algeria. He notes how the social and temporal logics of traditional Kabylia, of solidarity and honour, were eventually replaced by attitudes toward calculation and future profits. This led to “...conflicts in Kabylia society triggered by different forms of economic thinking and new practices which were ultimately destroying the traditional social order” (Beckert, 2014: 4). The main point to be derived from looking at the breakdown of a traditional society like this, Beckert argues, is to “...highlight the shift in temporal orientation as being at the heart of capitalism's unfolding dynamic” (Beckert, 2014). Beckert explores how economic decision-making amongst actors takes place in capitalist orders, and particularly so under conditions of uncertainty about the future:

...capitalism institutionalizes an organization of economic activity in which actors orient themselves toward an open and unforeseeable future. Such a future represents both unlimited possibilities for actors as well as a permanent threat to their economic status. At the macro level, the actions induced by this temporal order produce growth as well as sporadic crises, and thus the relentless dynamics of capitalism (2014: 1).

In an emerging capitalist order, actors ranging from companies to entrepreneurs, investors, employees and consumers must all orient their activities to a more open and uncertain future. “The temporary disposition of economic actors toward the future, and the capability to fill this future with counterfactual economic imaginaries, is crucial to understanding both how capitalism diverges from the economic orders that preceded it, and its overall dynamic” (Beckert, 2016: 2).

The paradox for both modernity and capitalism is that, ontologically, the future is open, uncertain, and by definition cannot be known. How, then, do actors orient themselves and make decisions? Beckert (2016) argues that actors have perceptions of the social world, and that they develop expectations about the future that in turn influence their decisions. But these decisions cannot be rational. Rather they are combinations of (i) what is thought to be currently the case (tomorrow will be like today), (ii) emotions, such as pride or status around imagined future states, and (iii) the expectations of others. Yet given that the future is unknown, they are in essence 'fictional expectations'. They are 'fictional' in that they provide an orientation in decision-making “...despite the incalculability of the outcomes” (Beckert, 2014: 9). They are ‘expectations’ in that they are social and not individual phenomena, and are shaped by collective beliefs formed from communicative practices ranging from laypeople to firms, politicians, experts and the media, and are crucial in the formation of imagined futures.

Fictional expectations refer to the images actors form as they consider future states of the world, the ways in which they visualise causal relations, and the ways in which they also perceive their actions as influencing outcomes. The term also refers to the symbolic qualities actors ascribe to goods that transcend the good's material features. These orient their decision-making despite the fact that the future in modern capitalist societies cannot be known. “Actors, motivated by an imaginary future state, organize their activities based on this mental representation and the emotions associated with it” (Beckert, 2016: 9). As a result, “in economic practice, fictional expectations take a narrative form, and become articulated as stories that tell how the future will look and how the economy will unfold into the future from the current state of affairs” (Beckert, 2016: 10). These stories are embedded in frames, which include an ensemble of economic theories, such as...
development, risk and calculation, or technological progress, and are mediated through the deployment of a range of technologies and instruments, such as maps, schedules, statistical trends, impact assessments, risk analyses, and so on.

There are four main ‘social’ implications of Beckert’s (2014, 2016) fictional expectations thesis. First, fictional expectations help actors work together in concert in the face of uncertainty. In the context of higher education, this may be universities aligning with governments to ensure that institutional risks are minimised, or universities within a region collaborating to minimise risk. Second, there are real-world consequences in that these expectations help to affect the future (that is they are performative), but they are also broader, in that economic theories are not the only framings of a situation with the potential to lead to outcomes, and they do not necessarily lead to the anticipated future. Third, the contingency of expectations is a source of innovation in the economy, giving rise to new ideas despite, and because of, uncertainty. And fourth, the contingency of expectations gives rise to a politics of expectations.

In the following section I illustrate how such a politics of expectations underpins the discursive, material and institutional work involved in imagining, socialising and normalising trade in higher education whilst faced with struggles over the meaning and purposes of education and its forms of governance. As we will see, actors’ different expectations and their associated imaginaries around education – as variously a public good, human right or tradeable service – have become the flashpoints around which political struggles over temporal orders and the future take place. This has led to efforts to limit the spaces for engagement by contesting actors through holding negotiations in secret and locking in progressive liberalisation so that the future is protected from distributional struggles.

4. The case: recalibrating time-future in education services, global markets and trade agreements

Global education services markets, and the inclusion of education in trade deals, are recent developments. A key concern in this paper is the implications of this shift for the temporal rhythm of the academy. Put in terms of a question, how have higher education actors’ orientations toward higher education markets, services economies and trade agreements been recalibrated and realised, and what does this mean for the temporal reorientation of the university and its actors in the higher education sector?

To help answer this question, I broadly focus on the dominant countries engaged in advancing education trade agendas – Australia, New Zealand, the UK and the USA – who by the 1960s were faced with major political-economic challenges to search for bases for long-term capital accumulation.

I draw on selected policy documents, statistics and other trade figures (particularly from Australia), where (mostly higher) education now features as a services sector to generate GDP (Robertson & Olds, 2018). As my focus is on the ways in which we understand efforts to shape the future, this case analysis offers an illustrative/exploratory rather than exhaustive account of the different ways we can see these processes at work.

4.1. Imagining higher education as a services sector

Most efforts to chart the process of reimagining public good sectors like education as key services sectors to underpin a new long wave of accumulation, point to the influential effects of the oil shocks in the 1970s and the economic crisis that followed. However, Harvey (2005) shows not only that the United States faced growing competition from Western Europe and Japan by the end of the 1960s, but also that newly industrialising countries in Asia had begun to challenge US hegemony during this period. Bell’s (1976) pronouncement that a “post-industrial” society had somehow emerged organically out of an industrial society was symptomatic of periods like this; that is, of attempts to reimagine a new kind of economy and society from a collapsing social order, and the conditions that might bring this about.

If the forecasters were now hard at work, so too were the ideologues over how best to manage the economy. What was clear was that the 1970s economic crisis had created a crisis of rationality over Keynesianism as the post-war model of development. At the same time, an alternative narrative was promoted by “a minority of ultra-liberal economic theologians” (Hobsbawn, 1994: 409) committed to a free market model as the engine for economic development. In Beckert’s language, this was an alternative story about the future, put into battle with an existing narrative. For Keynesians, high wages, full employment and the welfare state were represented as creating the consumer demand that fuelled expansion. For neoliberals, their story was that the future wealth of the nation depended on minimising the role and cost of government, creating conditions whereby the private sector would flourish and boost productivity.

In the years that followed, it was the ultra-liberal or neo-liberal neo/liberal imaginary of choice and markets, entrepreneurship, efficiency through competition, opening up public monopolies to private sector actors, and so on which won the day (Berger, Berger, & Kellner, 1974). This alternative vision of the future set in train a new kind of logic in sectors like education; one that privileged social attributes such as individualism, competitiveness, and forms of calculation aimed at maximising returns on education investments into the future. Most importantly, this neoliberal imaginary, with its cultural and institutional frames, was dependent upon and produced a new cognitive orientation to the future (Sennett, 2006).

If the governance of education was being refashioned in micro-economic policy through narratives such as human capital, consumerism, and efficiencies, so too was education being increasingly viewed in macro-economic policy as central to the development of a global knowledge and services-based economy (Robertson, 2009; Robertson, Bonal, & Dale, 2002). Indeed, by the end of the 1970s, trade in services was becoming a major component of international trade and accounted for an increasing proportion of international investment. However, services sectors present trading governments and
transnational firms with huge problems because of remaining protections around public services, or because domestic regulations around foreign direct investment inhibit the entry of transnational actors. Governments, allied firms and competitive organisations wanting to enter new markets in other parts of the globe argued that state monopolies on services, from telecommunications to banking, education and health, should be deregulated and opened up to competition, and to being included as a services sector, distinct from the production of goods (Marchak, 1991: 84).

Imagining and materializing education as a globally-traded services sector has taken, and continues to take, a considerable amount of political work, not least because education continues to be regarded in many societies as a public service. One reason for the easier alignment between the university and global services markets is that ‘internationalisation’ is central to the missions of most universities. Yet, here internationalisation itself has been transformed from being a knowledge claim around a cosmopolitan ideal to being understood as an economic strategy (Marginson & Considine, 2000).

A second reason for the easier alignment is that from the early 1980s onwards, governments in a small number of western economies (especially Australia, New Zealand, and the United Kingdom) took the view that higher education could offer them a comparative advantage in trade terms, and that they should therefore locate international education in their trade briefs and departments. Facing out to the Asian region in particular, ‘importing’ higher education provided an instant means for boosting income as a result of being able to charge full-fees. For cash-strapped universities having to expand access to a larger number of national students with the same resources, international students became a welcome source of revenues. The result was a spectacular increase in the volume of student movement from the Asian region to destinations like Australia and New Zealand, in turn transforming local infrastructures and cultures (Robertson & Kedzierski, 2016).

Trade in education services now constitutes an important ‘industry’ in countries like Australia, New Zealand, and the United Kingdom. Competition has led to major innovations in the sector, which now includes specialist firms like recruiters, the growth of for-profit universities which specialize in on-line learning aimed at part-time learners, new financial products aimed at extending student enrolment, new education divisions built into global firms that have realigned their investment strategies in line with projections around ‘emerging markets’, and so on. Yet with such a significant investment in, and dependence upon, the ‘education export market’, there is also concern expressed as to how best to maintain or increase market-share, and most importantly, how to ensure that governments don’t return to ‘national interest’ agendas and limit international investment in education.

Australia is a particularly interesting as a country in that it has gone furthest amongst the top services exporting countries in reimagining and strategizing the materialization of education as an education services sector. Education is described by the Australian government not only in trade terms as an ‘export’, but is placed into equivalence with other extractive resources traded on the global market – gold, coal and iron ore, as Fig. 1 shows.

Most recently, Australia has developed what it calls a comprehensive ‘international education’ strategy that projects well into the future – 2025. This projection this projection is justified by the extrapolation of the past, as Fig. 2 shows; a trend in the direction of increasing growth.

Its national and institutional level strategies are also shaped by gathering considerable amounts of data – some of which is available to the public, and other that is more granulated, and sold at cost to buyers (see Figs. 2 and 3). It engages in considerable amounts of horizon scanning, and produces a range of reports and ways of representing developments in the sector and their relation to the future. All provide a narrative linking the past and present with an assumed future of education as a services sector and part of global trade flows.

In May 2016, the Australian Government launched a National Strategy aimed at expanding the education services sector, composed of “...a trio of key strategies for the expansion of its international education sector: a national strategy for international education, a market development roadmap, and an alumni engagement strategy” (Australian Government, 2016, website) that would make use of innovations such as technology-enabled learning via online or blended delivery programmes. It is instructive to look closely as to how the future is imagined and strategized using techniques and devices

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**Australia's top 25 exports, goods and services, 2012**

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<th>Rank</th>
<th>Commodity</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>% growth 2011 to 2012</th>
<th>5 year trend growth</th>
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<tr>
<td>1</td>
<td>Iron ores &amp; concentrates</td>
<td>49,380</td>
<td>64,097</td>
<td>54,689</td>
<td>-14.7</td>
<td>28.7</td>
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<tr>
<td>2</td>
<td>Coal</td>
<td>42,967</td>
<td>46,691</td>
<td>41,273</td>
<td>-11.6</td>
<td>10.6</td>
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<tr>
<td>3</td>
<td>Gold</td>
<td>14,438</td>
<td>15,077</td>
<td>15,525</td>
<td>3.0</td>
<td>4.9</td>
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<tr>
<td>4</td>
<td>Education-related travel services</td>
<td>16,597</td>
<td>15,155</td>
<td>14,487</td>
<td>-4.4</td>
<td>2.7</td>
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<tr>
<td>5</td>
<td>Natural gas</td>
<td>9,425</td>
<td>11,084</td>
<td>13,418</td>
<td>21.1</td>
<td>17.4</td>
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*Fig. 1. Australia’s top 25 exports, goods and services, DFAT, 2012 (http://fat.gov.au/publications/tgs/index.html).*
such as ‘forecasting services’ by global accounting firms, ‘roadmaps’ (with identified competitors), social groups like ‘alumni’, and other kinds of networks, always in terms of trade and investment.

The National Strategy for International Education 2025 itself, which reflects a “whole-of-sector” approach and sets out a 10-year plan for further developing Australia’s position as a global leader in education and training. The national strategy is based around three pillars: “strengthening the fundamentals” (including improvements to student services and quality assurance), “making transformative partnerships” (which focuses on links at home and abroad, alumni networks, and visa policy), and “competing globally.”

The Australian International Education 2025 (AIE2025) market development roadmap, is the product of both extensive consultations within the sector and research from Deloitte Access Economics. It provides a 10-year market development framework for Australia’s education exports, including “game-changing” strategies to build scalable, collaborative networks of education providers, attract capital to fuel the sector’s expansion, and target key markets abroad.

The Australia Global Alumni Engagement Strategy 2016–2020 outlines a five-year plan to strengthen and engage Australia’s foreign alumni with the broader goals of enhancing the country’s diplomatic access and influence and building trade and investment links.
“This signals the sector’s and the government’s commitment to work together to advance international education by identifying new products and new opportunities for expansion, and building on our current presence in existing markets,” said Minister Colbeck

The temporal lexicon around the future is distinctive in this strategic policy document: a ‘ten year plan’, ‘game changing strategies’, ‘expansion’, ‘future innovations’, and so on. The stakes are high for the government and so are the potential risks of losing market share, given that international education is estimated to be worth AUSS19.6 billion (US$14.7 billion) a year to the Australian economy; it is the nation’s third largest export sector. As competition has stepped up, so too have concerns over who has what share of the global education services market, and how that might play out in the future. Key actors (governments, institutions and transnational firms) within economies that include Australia, New Zealand and the United States, have intensified their interest in the ways in which domestic and international regulatory systems of the inter-state world currently or might into the future, impede the project of creating an expanding global trading system in services – an issue I now turn to.

4.2. Globalising cognitive frames and orientations—but failing

Transforming higher education from being widely understood as a public good into a global services sector governed through global trade rules requires complex processes of reframing, normalising and socialising via a range of devices, institutional arrangements, and new social relations. To be successful across global space, this process requires the globalising and embedding of new cognitive frames.

Challenging the cognitive and material barriers to global trade in services has been on the agenda since the early 1980s, spearheaded by service coalitions formed to lobby for change, including the US-based Coalition of Service Industries (CSI). The CSI used its lobbying capacity to shape negotiations taking place under the General Agreement on Tariffs and Trade (GATT) during the 1980s, to include services and not just goods in the mandate of the GATT. Organised interests in the United States as well as Australia, New Zealand and the United Kingdom were keen to promote a new post-GATT structure, the World Trade Organization (WTO), with an expanded trade agenda.

In 1995 the WTO was launched to “. . . formalize, deepen and widen an international system of trade regulation. It was also to bring greater coherence to global policymaking by drawing together the work of the WTO with that of the IMF, the WB as well as to develop relations with other bodies” (Wilkinson, 2002: 129). The WTO now presided over the GATT, along with two new areas of trade, the General Agreement on Trade in Service (GATS), and Trade Related Intellectual Property Services (TRIPS).

Members who joined the WTO opted in under a single undertaking to a series of binding rules and a built-in agenda to engage in ongoing negotiations leading to progressive liberalisation into the future. A complex set of technologies and devices to secure this cognitive orientation to the future also determined the work of the actors and their relations to each other, from frameworks of rules laying out obligations governing trade in services, to annexes on specific services sectors, and schedules detailing the liberalisation commitments of each WTO member. An exemption would only be granted under GATS Article L.3 (c); as " . . . supplied neither on a commercial basis nor in competition with one or more service suppliers" if the service could show that it existed in a completely decommodified form, untainted by the market.

The GATS mechanisms are worth dwelling on because of their distinctive temporal and cognitive orientation to the future. The first is progressive liberalization. This means that becoming a member of the WTO (there are now 162 countries) means that a country must commit to ‘free trade’ policies into the future. Second, negotiations around agreed sectors followed a ‘positive list’ schedule. The member state lists those service sectors and modes that it is prepared to negotiate over and commit whilst the rest are excluded from the agreement. Switzerland, for example, only committed its private universities in its GATS agreement. Third, once the agreement is in place, the rights of the investor take precedence. Any government who decides to limit or curtail investment, or indeed nationalize a sector (perhaps as a result of a shift in political ideology), will be asked, via a dispute settlement mechanism, to pay the investor future lost income. This asymmetrical relationship between investors in education services and the needs of a community regarding education is an example of what Beckert (2016) refers to as a relationship between instruments and distributional struggles.

Despite efforts to lock in a particular cognitive orientation to the future that reflected the interests of investors in education, the GATS negotiations proved to be hugely controversial and in the end largely failed. Each meeting was marked by protests; the iconic Battle in Seattle in 1999 was hugely resonant. Between meetings, campaigners organised and promoted education as a human right and not a commodity. To do so, they enrolled a competing narrative to promote a different imaginary around the future. Campaigners pointed particularly to the right to education as recognised in international instruments – most prominently the International Declaration of Human Rights launched in 1948 after World War II, and the Convention of the Human Rights of the Child launched in 1959. In a specially commissioned report on GATS, the Special Rapporteur for Education stated that the “rapid development of international trade law necessitated a decisive reaffirmation of education as a human right” (Tomasevski, 2001: 5). This led the Rapporteur to observe

. . . the liberalization of trade in services, without adequate government regulation and proper assessment of its affects, can have undesirable effects. Different service sectors require different policies and time frames for liberalization and some areas are better left under governmental authority (p. 20)...While the WTO Agreements provide a legal framework for the economic aspects of the liberalisation of trade, they focus on commercial objectives. The norms and standards of

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human rights provide the means of providing a legal framework for the social dimensions of human rights...A human rights approach to trade liberalisation emphasizes the role of the State, not only as negotiator of trade rules and setter of trade policy, but also as duty bearer for human rights.

In her report, the Commissioner pointed to the different ways in which GATS, were it to be implemented, might exaggerate social inequalities in education if the state was unable to have a degree of flexibility over the organisation of education.

From a commercial perspective, holding countries to their commitments to liberalise is important to ensure transparency and predictability in international trade and the payment of compensation is a legitimate commercial response to the settlement of disputes. From a human rights perspective, however, the focus is less on predictability and more on the need for flexibility to modify or withdraw commitments to liberalise services where experience demonstrates that a commitment constrains or limits the enjoyment of human rights. The need for flexibility is particularly relevant for developing countries given that they are in a dynamic process of building infrastructures. ...Moreover, while compensation to affected parties might be appropriate in some cases upon withdrawal of commitments, a human rights approach would question whether states should be sanctioned for taking action to protect human rights (2001: 28).

These very publicly aired concerns, along with growing disquiet amongst many developing countries as to what free trade really meant for their economic development more generally, resulted in the WTO GATS negotiations stalling by 2005. The inability to convince other actors in the economy to share in similar expectations about education as an investment sector means this future is not likely to be realised (Beckert, 2016: 275). As a result, the strategy failed to also shape actors' cognitive orientation toward education's future as a services sector subject to WTO rules.

4.3. The 2008 global financial crisis—a new narrative and strategy

Crises generate new semiotic and material opportunities, opening the space for new accounts of what is to be done to shape and secure the future. By 2011, a new wave of mega-trade in services negotiations had begun in earnest, stimulated by the global financial crisis in 2008, the decline in productivity in Europe and the United States, and growing unemployment (Robertson & Komljenovic, 2017). Education as a ‘services sector’ was again on these agendas, though those contesting its inclusion continued to point to its public good and not private or trade status.

These negotiations included the Trans-Pacific Partnership (TPP) involving 12 countries in the Pacific Region dominated by the United States; the Comprehensive Economic Trade Agreement (CETA) between Canada and Europe; the Transatlantic Trade and Investment Partnership (TTIP) involving Europe and the United States; and the Trade in Services Agreement (TISA) largely between OECD countries. However, this time all negotiations have been held in secret, and all involve frameworks and instruments that aim to lock in the interests of investors into the future.

This more coercive, secretive approach to realigning interests is a fraught one, as the lack of shared expectation about the future of education as a services sector places limits on its potential to get traction on, and control, the future. The formal withdrawal of the United States from the TTP (and likely TTIP) following the election of Donald Trump to the US Presidency in late 2016 is a case in point. Trump’s appeal to US voters is that he argued they did not share in the view that global trade deals were good for American workers and their jobs.

Nevertheless, these mega-trade deals are negotiations that have been completed (with CETA, TPP awaiting final approval by the various members) or are continuing (TISA, TTIP). This raises the question as to how the future for education is imagined, and what kinds of discourses, devices, institutional arrangements and social norms are being deployed to do the work of creating shared expectations about that future and the temporal order of capitalism.

One such device is the ‘Impact Assessment’ used to convince sceptics and enrol promoters, and thus align expectations, as to the longer-term outcomes of these deals. The Impact Assessment for TTIP was conducted by the Centre for European Policy Studies (CEPS), a pro-business think-tank located in Brussels (see Pekmans, Lejour, Schrefler, Mustilli, & Timini, 2014). This Impact Assessment was used by the European Commission to project the annual gains to be had from the TTIP of €119b for the EU and €95b for the USA, suggesting that European countries would be the main beneficiaries.

This particular approach to Impact Assessments makes specific assumptions about capitalist markets and futures. De Ville and Silles-Brügge (2015) show that the TTIP Impact Assessment depends on Computational General Equilibrium Modelling (CGEM). CGEM embraces neoclassical economic assumptions: there is no excess demand, all markets clear under conditions of perfect competition, and we can model market processes through numerical data and results. Yet De Ville and Silles-Brügge (2015) argue CGE models have been subject to critique, even within economics, in that there are information asymmetries, individuals are often driven by more complex sets of values, and labour and product markets rarely clear at the same time. The CGEM is used to model three kinds of policy options; from a baseline option to a comprehensive and ambitious one, of removing all duties, reducing tariff and non-tariff barriers (NTBs) on goods and services, and on government procurement. For the base-line option, the gains are negligible. The gains on the more comprehensive scenario, the one used by the Commission to make the economic case for TTIP, are presented as more substantial. And it is this latter future that is used by the Commission in its public defence of TTIP.

De Ville and Silles-Brügge (2015) argue that this kind of Impact Assessment acts like a black box; it not only skews the terms of the economic and political debate in directions that suit the Commission’s agenda, but also has a particular narrative
that it offers of the future. This future does not include the costs that result from macro-economic adjustments – such as alignment to new standards, the displacement and retraining of workers, potential welfare losses in the society, or the threat to public policy goals (De Ville & Silles-Brügge, 2015: 669). In contesting this Impact Assessment narrative, De Ville and Silles-Brügge (2015) present the case of the North American Free Trade Agreement, which also used the CGEM. They compare the ex-post evidence with the ex-ante claims which show that both Mexico and Canada fared significantly worse than predicted in terms of economic gains (especially around costs over labour displacements). In relation to TTIP, they argue a combination of the assumptions built into the CGEM, the regulatory mechanism to be used, and the capacity to liberalise across the board, exaggerate the potential economic benefits of TTIP whilst under-playing other likely outcomes – such as a race-to-the-bottom in social, educational and environmental standards.

A second temporal device in these trade deals is ‘the ratchet effect’. Any new activity in the sector into the future will be subject to the principles of the market and the interests of the investors, as enshrined in the trade agreement. The ratchet process aims to draw more and more of the society into functioning like a capitalist market. Linked to this is a third device that now works the opposite way to the GATS; it deploys a negative and not a positive list. A negative list means identifying all those activities that are to be excluded so that what is not on the list is included. The expectation is that the negotiators have a god-optic on the present and the future; as an all seeing and knowing eye that can see sufficiently to know what to anticipate. Through these two devices, we see education traders and investors colonising the future of higher education, sanctioned the governments’ negotiators, so that the future is not locked in as a resource for global capitalism.

5. Concluding thoughts: higher education and temporal order of capitalism

I began this paper by arguing that higher education, as a knowledge-producing sector, has its own temporal rhythms and ordering processes. One temporal modality is toward the past, as accumulated knowledges become resources for the present, and as academics carry out their work as curators and custodians. A second temporal modality is toward the present via the unfolding of a day, term and year, and the patterns of teaching, learning, marking, researching, administering, that punctuate, thus creating the rhythm of an academic year in particular way. A third modality is the future – one marked by the uncertainty of the research process, the serendipity of the unexpected, and the happy coincidences that turn into something – perhaps a Nobel Award.

There is little doubt the academy is being challenged not only to be efficient in our use of time and more certain in what we do. These developments are about controlling the present and the future. Yet to a large extent, they are also the outcomes of the leakage of the dynamics of capitalism into the academy, as higher education is increasingly drawn into becoming a value-producing sector in its own right.

Yet it is through looking more closely at the ways in which higher education futures are regarded as resources to be reimagined, colonised and exploited for the purposes of investor certainty, that we see the full import of a different temporal imagination and rhythm on the sector. These trade agreements aim to not only transform the future into an extended present (Nowotny, 1994), but the extended present contains the progressive cognitive reorientation of actors to a future shaped by capitalist dynamics (Beckert, 2016). This case helps to generate new insights around time future in a substantive sense, and might become the basis for further theoretical work of the kind that Nowotny and others have called for.

And if time is political and higher education is also in a normative sense one of the spaces that we might use to think critically about the future, then our social theories can be put to work to change the current state of affairs. In this regard, I have shown that ongoing efforts to commodity higher education, on the one hand, and to colonise higher education futures exclusively to serve the interests of economic investors, on the other, continue to be contested. Destabilising these possible futures are the huge contradictions that now emerge, particularly for higher education institutions, and the risks to knowledge production more generally as higher education gets more tightly wound into the circuit of capital, its temporalities, the dynamics of capitalism, and tendencies toward crisis.

However, this new temporal order is yet to become common sense, and the existing order is yet to die. Competing narratives about the future of higher education and higher education’s futuring thus open the space for recognising the importance of contesting these narratives and the devices and other mechanisms aimed at socialising and normalising one narrative over another. And if the future is a resource to be claimed, then maybe we might also begin the process of imagining a future to be realised through an alignment of expectations that places knowledge, openness, sharing and community as an alternative cognitive orientation toward the future.

References

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Original research article

Carpe the academy: Dismantling higher education and prefiguring critical utopias through action research

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\section*{1. Introduction}

The word “dismantle” comes from the Old French manteler, or fortify, to describe a process of destroying fortifications. But the original meaning is to uncloak, from the Latin mantellum for cloak. As action researchers and educators located within the academy, we are committed to nothing short of dismantling the university, in both senses of the word. To expose the systems which continue to privilege some learners over others, some forms of knowledge over others, and some financial interests over others. And at the same time to challenge the structures—organizational, economic, social, cultural, and physical—that
keep the communities in which these institutions exist at bay and allow universities to continue to hoard intellectual and financial resources which by rights should be public property.

Criticism of the university’s aloof positioning as a so-called ‘ivory tower’ has long been a theme in popular and critical discourse, but the current rhetoric across many university administrations alludes to a more publically engaged stance. Often this is an illusion, and one in which even well-intentioned participants (ourselves included) can become complicit. We liken this to the ha-ha—a structure peculiar to the great country estates of Britain and France which appear from within to provide an unbroken expanse of perfectly manicured lawn extending to the woods and fields beyond. But look back at the house from outside and you see a tall stone wall or alternatively a ditch preventing the attractive but destructive deer from getting anywhere near the expensive shrubbery. This is the modern university campus—surrounded with invisible walls and barriers to prevent unwanted entry while giving the impression of free access and welcome to all. This can take the form of physical barriers like restricted access to campus buildings and facilities, financial barriers to potential students such as high tuition fees and class schedules not designed to accommodate the needs of working students, administrative and policy barriers like research funding structures that provide huge overhead costs to universities but see any payment to local participants as dangerous forms of coercion, or structures of faculty hiring and promotion that put a premium on money raised or on journal rankings that have little to do with contributing to the public good.

Consider the following scene, which took place recently at the University of Cincinnati. The senior administrator chairing this particular meeting looked around the table at a group of faculty drawn primarily from the arts, humanities, and education. He had dubbed the group Pathway B, the more clearly to distinguish us from our more lucrative colleagues in Pathway A. With what was intended as a look of benevolent concern, he spoke to the group, making a point of meeting each person’s eyes as he spoke. “Each of you has intellectual property”, he intoned. Then after a long pause to indicate the import of his next statement: “And I’m here to help you commercialize on that intellectual property.” With a bit more honesty than diplomacy (a consistent character flaw), I, Mary, responded, “I don’t want to commercialize on my intellectual property—I want to give it away.” His reply was quick and to the point: “Not at my university.”

The position taken by this administrator is symptomatic of higher education systems that are increasingly corporatized rather than democratized. Our call in this paper is for those of us who resent such a trend to actively resist it, to re-claim and ‘carpe the academy’: following the Latin meaning of the word, to seize, enjoy, and make use of it as a collective public good.

This is a demanding and precarious project, but one that we see as preferable to allowing the capture of the university by neoliberal logics to continue unencumbered. The push to commercialize knowledge, to engage in never-ending competition for rankings of faculty productivity, to standardize and measure isolated bits of information and call that learning, to sell off research to the highest corporate bidder (Church, 2008; Lewis, 2008), to saddle students with exorbitant amounts of loan debt (Johannsen, 2012; Ross, 2012; Weil, 2013), and to increasingly rely on contingent labor to fill faculty roles, while paying university administrators (not to mention athletic coaches in the American context) ever higher salaries (Academe, 2016; Bishop, 2011; Sauter, Stebbins, Frohlich, & Comen, 2015) are all leading us away from the kinds of critical thinking, creativity, open exchange of ideas, and compassion necessary if we are to provide a meaningful education to our students and together with them take an active role in addressing the problems facing the world.

Many others have identified as problematic the encroachment of neoliberal agendas and imperatives on higher education (see Amsler, 2011, 2014, 2015; Canaan & Shumar, 2008; Facer, 2011; Greenwood, 2007, 2012; Motta & Cole, 2014; Motta, 2013; Wildman, 1998). By neoliberalism, we refer to

the doctrine and campaign for internationalization of market economy, for intensive society-wide privatization as well as extensive globalized market deregulation . . . [which] include[s] stunning increases in poverty and inequality worldwide . . . as well as considerable authoritarianism in defense of market prerequisites by national and international actors. (Collins, 2008, xiv)

Our experience is of universities in the United States and United Kingdom, and yet the geopolitical scope of the issues addressed here is much broader, as universities across the developed world are subsumed into what from a neoliberal viewpoint is framed positively (or at least neutrally) as a ‘global knowledge economy’ (Shore, 2010). Instead, critics argue that the global commodification of higher education serves to entrench international inequality to the detriment of developing countries (Naidoo, 2008) and to further devalue, colonize, and coopt indigenous epistemologies and practices (Brayboy, Castagno, & Maughan, 2008; de Oliveira Andreotti, 2016).

Informed as we both are by critical, liberationist, social-democratic, and other broadly leftist political ideologies, we problematize the ascent of the increasingly corporatized university in large part because of the neoliberal realist position on the future that it perpetuates: a totalitarian view which claims that there is no alternative to neoliberal capitalist market principles and that present and future realities can diverge only to the extent permitted by existing market forces and rationales (Amsler, 2011). It is true that the alternatives seemingly open to us, even in our privileged positions within universities, are all too few: this is precisely the point. For all the internal and public-facing rhetoric about innovation, universities across North America, Western Europe, and beyond increasingly find themselves peddling severely unimaginative versions of ‘the future’, in which market imperatives continue to reign, substantially unchallenged, and in which the wares and fates of higher education are evermore funneled towards promoting neoliberal agendas and private economic wealth generation above all else. In this context, education takes the form of preparing and socializing the next generation of workers: a future focus severely limited in the possibilities it considers. Thus we are faced with a mutually-
constitutive relationship where limited visions of future needs and demands serve to constrain present educational offerings: a self-reinforcing dynamic admitting little disruption.

This is part and parcel of a deeper pedagogical problem, namely, that the encroachment of neoliberalism in all areas of life has weakened how and what people learn, and the skills and sensibilities they develop (Amsler, 2015). Collectively, we are less equipped than we could be to respond to complex social and political challenges from positions of openness, possibility, recognition of difference, and participation within processes of becoming. Our presents are impoverished as a result, and so too are our futures. As academics, one of the key ways in which we can resist the capture of the university by neoliberal logics is to develop forms of knowledge production and organizing that are purposefully present- and future-opening, and necessarily also radically democratic (Amsler, 2015). With Firth (2013), we argue for utopian epistemologies, methods, and praxis that do not reduce or recuperate transformative, transgressive otherness . . . a methodology that does not assume or impose values and desires but rather explores and valorizes processes of desiring-production (Deleuze & Guattari, 2004, p. 35) whilst owning the impossibility of taking a value-free approach to . . . research. (p. 256)

In this paper, we propose action research as a radical methodology for pruning open and organizing democratic spaces—within, alongside, and beyond the academy—in which it becomes possible to think more expansively and critically about both presents and futures. Our argument is that action research processes offer us a means for keeping open, rather than shutting down, diverse and transgressive possibilities and debate around the nature of the educational offerings, pedagogical practices, and scholarly commitments we collectively desire for higher education. Action research can help us respond to Barnett’s (2013) call for us to see beyond “the corporate university, the entrepreneurial university, the marketized and the bureaucratic universities” (p. 21), and to work together to generate what he refers to as “feasible utopias” of the university.

Our argument proceeds as follows. We begin by outlining the implications of the dominant neoliberal paradigm for how we conceptualize and respond to notions of the future within higher education. We propose action research as a productive means of engaging with the challenge of re-imagining higher education, positioning this as a critical utopian and prefigurative project which also involves enlightened recognition of the entanglement between presents and futures. In framing the interventions we believe are required in this way, we reflect on what the traditions of critical utopianism and prefigurative politics can offer us. In the latter part of the paper, we introduce two action research approaches, critical utopian action research and systemic action research. We present these as two examples (amongst many) of present- and future-expanding forms of knowledge production that could be mobilized by groups within and alongside the academy to challenge and organize against the neoliberal capture of the university and educative practice more generally.

An important caveat: bringing these traditions to bear on ongoing efforts to disrupt and transform the academy are neither a silver bullet nor unproblematic, not least to the people involved. We do not wish to overemphasize the radical potential of academic networks and initiatives which are almost necessarily limited by their very existence within, or at the edges of, prevailing systems. We align ourselves with present debates about the tensions involved in working for radical change within, against, and beyond the neoliberal university, and agree that these can be experienced as contradictory, self-limiting, and colonizing (Canaan, 2008; Darder, 2009; Gill, 2009; Motta, 2013). And yet, with Amsler (2015), we are convinced that “radical democracy is difficult but possible even in situations of political foreclosure” and that “embracing it as a creative and critical learning process greatly increases our chances of making it work” (p. 12). This is where we believe action research has a critical role to play.

2. Problematizing dominant neoliberal realist positions within higher education

At present, dominant ways of thinking about ‘the future’ within our sector are entrenched within a neoliberal worldview that foregrounds formal education’s role in supporting economic wealth generation and the ongoing concentration of power in the hands of the elite (Amsler, 2011, 2014; Greenwood, 2012; Facer, 2011; Slaughter & Rhoades, 2004; Washburn, 2005). One manifestation of this is the way in which the value of education is framed in terms of future returns that are predominantly economic, instrumentalist, technocratic, and individualist in nature. Degree programs are increasingly ‘sold’ to prospective students and their parents (higher education’s ‘consumers’) on the basis of graduates’ future employability and earning power. Of course, in the past this was not necessary because higher education was geared towards those who already had a sound economic future by virtue of inherited wealth and privilege. We are categorically not arguing for a return to those days. We sympathize with parents’ and students’ need to feel assured of future livelihoods in contexts that are increasingly hostile to young people starting out in the world (not least given ever-higher tuition fees and student debt). And yet we also lament the seeming constriction of the perceived value and role of higher education.

There are many reasons why neoliberalism is deeply problematic, not least of which is the exponential expansion in “inequalities in wealth, power and possibility” (Amsler, 2011, p. 48) to which it gives rise, despite promises to the contrary made by the power elite whose interests are bolstered by deregulated markets. Although dominant neoliberal discourses frame the value of higher education in terms of its contribution to national productivity and economic growth, and primarily worthy of public and private investment on these grounds, the truth is that nationally (both in the US and UK) and globally, inequalities are growing, not retracting. Criticism continues to grow of what is increasingly perceived as an “Economy for the 1%” (Oxfam, 2016). The encroachment of neoliberalist imperatives on all aspects of life severely hinders our ability to contribute to more equitable futures, which we see as the unrealized promise and ethical obligation of education (Dorling,
Greenwood (2007) has argued forcefully for the need to challenge the neoliberal administrative and policy practices which impede higher education from more fully working with wider and ever-more diverse communities to address pressing social, economic, and environmental problems. As he notes, “the internal incoherence of the neo-liberal program of higher education creates self-contradicting reforms that are causing ongoing crises in the educational systems of most industrialized countries” (p. 116). The application of ‘new public management’ systems and (pseudo-)market logics to supposedly hold higher education accountable, most often by the promulgation of quantitative measures and forms of assessment, continues to have a counter-productive impact on the ability of universities to function for the public good. This was highlighted over a decade ago by Rhind’s study on the impact of these mechanisms on social science research in Britain (Commission on Higher Education, 2004), which showed that “they decrease collaborative research, increase short-term research projects that promise speedy publication, and focus inward on disciplinary audiences and away from more public venues for the dissemination of social science research” (Greenwood, 2007, p. 118).

A key problem, we argue, is the neoliberal realist position on the future assumed within broader neoliberal, capitalist systems. Ontologically, such a position assumes that there is no viable or desirable alternative to neoliberal capitalist market principles, thereby setting a very narrow band within which present and future realities can diverge. The future is to all intents and purposes a continuation of the present (Firth & Robinson, 2009): threats and opportunities are understood in relation to the status quo as, on balance, a good thing. To the extent that the future holds possibilities to accelerate the expansion of the neoliberal cornerstones of free market, economic growth, privatization of the means (and returns) of economic wealth generation, and intensification of corporate power, the future is bright. To the extent that these things are radically challenged or unsettled, either ideologically or practically, the future is grim: a communist-like dystopia in which freedom and individuality are curtailed, living standards take a nosedive, and all are substantially impoverished.

Either way, what the future is—the possibilities, resonances, and potentialities it is perceived to hold, for better or for worse—is made sense of using predominantly the same neoliberal imperatives that structure our present. For example, all manner of innovation is ostensibly encouraged—so long as the outcomes are seen as consistent or co-existent with, and certainly not as threatening to, neoliberal agendas and existing distributions of power. For new degree programmes to progress beyond pipe dreams, business cases must be proved, in which market demand, efficiency savings, and expected financial returns, rather than societal need or redistribution of the possible, are deciding factors. Managerialist and market logics increasingly shape what is expected of the educator role (De Angelis & Harvie, 2009). Dominant discourses compel us to accept these present realities and follow through on their future implications while constraining possibilities for critique and dissent in the present, in what Amsler (2014) refers to as “one particular manifestation of a wider culture of ‘contracting possibilities’” (p. 276).

How has this contracting of possibilities become internalized within large segments of higher education? Reviewing the then emerging literature on higher education in the 21st century, Skolnik (1998) identifies a persistent concern with the threats posed by globalization to higher education institutional and employee survival. The implication is that these perceived threats “will soften people up for change” (Skolnik, 1998, p. 638). The more we are persuaded that the sector’s future is bleak and that our very existence is threatened, the more likely we are to accept increased austerity, performance management, and productivity pressures as necessary evils. Of particular interest is the trouble taken to present such processes of contraction as driven by impersonal forces; as the neutral result of free-market transactions representing the subjective preferences of millions of consumers, end users, and stakeholders (Skolnik, 1998). This perceived impersonality and abstraction adds another layer of seeming inevitability, which Skolnik calls into question: “[O]ne can not help but wish for a clearer picture of who the key instigators, decision-makers, and opinion leaders are, and of how they are influencing the process” (p. 638). In such a context, and absent opportunities for deep structural critique and dissent, change is experienced “as a symptom of . . . powerlessness rather than as the product of . . . agency” (Kompridis, 2006, p. 267, cited in Amsler, 2014, p. 276). In other words, those of us forming part of higher education are more likely to see present circumstances, and the (re)actions they call forth from us, as compelled by external structures and demands, and outside our sphere of influence.

The elephant in the room is the mutually-constitutive relationship between impoverished imaginaries about what the future holds and what demands this will place on us, and ever-narrower educational offerings and institutional spaces in the present. The less we expect of the future, the less we demand of the present. The less the future seems radically open, the ever-more standardized, homogenized, and hegemonic our educational and organizational presents become. With Amsler (2014), we agree that it is important that we “challenge this condition of ‘disimagination’ by bracketing these hegemonic imaginaries of education and creating conceptual and discursive space for the disclosure of alternatives” (p. 276). This, we argue, is the potential offered by action research, which we believe speaks to the need articulated by Firth (2013) for “a research praxis that critically recognizes the utopian and pedagogical nature of the research process itself and its products or outputs” (p. 257) and that “valorizes the research process itself as a site of utopian desire that mutually transforms researcher and participant” (p. 268).

3. Action research as prefigurative and critical utopian practice

Broadly speaking action research is a term used to describe a family of research methodologies which seek to . . . bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their
communities... and to contribute... to a more equitable and sustainable relationship with the wider ecology of the planet of which we are an intrinsic part. (Reason & Bradbury, 2001, p. 1-2)

Drawing upon a range of theoretical, epistemological, and political foundations (Gayá, Reason, & Bradbury, 2008) and spanning multiple academic disciplines, geopolitical contexts, and arenas of practice, one way of describing what brings all these approaches to action research together is a shared values stance. This has been defined as, “a respect for people and for the knowledge and experience they bring to the research process, a belief in the ability of democratic processes to achieve positive social change, and a commitment to action” (Brydon-Miller, Greenwood, & Maguire, 2003, p. 15). These principles challenge significant aspects of conventional post-Cartesian science, which generally value objectivist, positivist descriptions of the world, and in which dualisms abound: “knowledge is presumed to be pitted against practice, mind separated from heart, reflection from action, expert from lay person, self from other, etc.” (Bradbury, 2015, p. 3). Although recently there has seen an upsurge in experimentation with knowledge democratization and co-production within and beyond the academy (see for example Facer & Enright, 2016), the fact remains that “in many knowledge systems, cooperating with marginalized and non-elite subjects is regarded as a liability to professional reputation” (Amsler, 2014, p. 279). Dualistic divisions of labour— with the expert academic seen as the font of universal theoretical knowledge, and practical, experiential, or embodied knowledge considered the lower-status product of practitioner communities—serve to cloud our recognition of the entanglement between knowledge-production and present/future possibilities. As Firth (2013) argues, “devaluing local, particular, and embodied knowledge... leads to the invisibilization of prefigurative and immanent utopian knowledges” (p. 260).

We see the unlearning of worn, taken-for-granted norms and habits of conventional social science as necessarily going hand in hand with the dismantling of the modern, neoliberal university. But as anyone experienced in social activism and resistance will know, the status quo is frustratingly resilient, and challenging existing power structures extremely difficult. We do not suggest that action research is a panacea, by itself capable of accomplishing such an extraordinary feat. Instead, we argue that action research may be understood as eminently present- and thus future-expanding by virtue of its functioning as prefigurative, critical utopian practice.

Originally defined as the desire to embody “within the ongoing political practice of a movement... those forms of social relations, decision-making, culture, and human experience that are the ultimate goal” (Boggs, 1977, p. 100), prefigurative practice seeks to enact in the here and now the world(s) we desire. In accounts of the politics of social change, this has been theorized as a shift from a “politics of demand” linked to traditional approaches of protest, opposition, and civil disobedience to a “politics of the act” (Day, 2004). A politics of the act requires giving up the expectation of a nondominating response from structures of domination; it means surprising both oneself—and the structure—by inventing a response that precludes the necessity of demand and thereby breaks out of the loop of the endless perpetuation of desire for emancipation. (Day, 2004, p. 734)

Following Day (2011), Amsler (2014) refers to this as a “politics of possibility”, prefigurative in that “it aspires to create new worlds that embody and enact not-yet futures by using the resources of the existing world, paying particular attention to the micro-politics of space, time, language, the body and the emotions through which the power of these resources operates (Gibson-Graham, 2006)” (p. 280). Thus, prefigurative practice is immanent, rather than transcendental, and in keeping with contemporary utopianism, its utopian impulse is present-focused, rather than primarily aspirational—it is concerned with the enacting of hope and desire in the present moment, rather than with the establishment of ideal future blueprints (Firth & Robinson, 2012). Prefigurative practice emerges from within the field of lived, embodied experiences, from alternative knowledges, politics, practices, and forms of organizing made manifest in the here and now. Rather than focus on abstract or absent futures, prefigurative politics responds to and folds back into present space, Exhibiting an approach to social change “based on the ability to transform individual consciousness through immanent practice and to transform society by means of example” (Firth, 2013, p. 264). A distinct aspect of prefigurative practice is that it challenges the temporal disconnect between present struggle and future goals: “instead, the struggle and the goal, the real and the ideal become one in the present” (Maehlerbergh, 2011, p.4).

Action research is nothing if not prefigurative. Central to action research practice is the ongoing, day-by-day commitment and hard work required to craft relationships, spaces, and processes that make manifest the qualities and characteristics of the kind of social science and radical democracy to which we aspire (Arieli, Friedman, & Agbaria, 2009; Bradbury & Torbert, 2016; Brydon-Miller, 2009; Brydon-Miller, Rector Aranda, & Stevens, 2015; Gayá & Reason, 2009; Greenwood & Schafft, 2003; Guhathakurta, 2015; Hilsen, 2006; Marshall, 2016; Tofteng & Husted, 2006). Action researchers do not just advocate for a different type of social science. They do not see the transformation of social science and the democratization of knowledge-production as primarily aspirational projects, realizable only in an ideal future. Action researchers purposefully stand and, moreover, act in opposition to the exclusionary and recuperative assumptions, values, and practices of the academy alongside which it exists. Adopting action research orientations and practices allows us not only to espouse, but more importantly to enact in the imperfect yet always becoming present, a direct challenge to the privileging of “performativity over humble co-operation, abstraction over praxis, individual knowing over collective learning, and monological solution-giving over dialogical inquiry (Motta, 2011)” (Amsler, 2014, p. 279). In this way, we breathe life into what post-left anarchist Bonanno (1988) refers to as a “propulsive utopia”, one which “exists in the field of becoming and agency” and in which the utopian idea is experienced as an “affective reality” (Firth & Robinson, 2012, p. 248).
The notion that utopian practices can be *propulsive* rather than merely prefigurative (of an ideal future) gives us pause to consider the energetic and transformative thrust, the expansion in possibility, that emerges from actualizing the utopian affects of hope and desire in the present moment. Action research shares at least some convictions with post-left anarchist theory, amongst which is the belief that other worlds *are* possible, now.

This is what radical methodologies such as action research offer those of us intent on dismantling and reclaiming the university: “lines of flight” from capitalist modernity rooted in the immanent present (Firth & Robinson, 2012). Many approaches to action research might be brought to bear on this project. We offer two examples: the first, critical utopian action research (Bladt & Nielsen, 2013; Nielsen & Nielsen, 2006; Tofteng & Husted, 2014), to which we now turn, illustrates the critical, prefigurative, and propulsive utopian elements of action research.

### 4. Critical utopian action research

Founded in the work of Kurt Aagaard Nielsen and Birger Nielsen among others (Nielsen & Svensson, 2006), critical utopian action research (CUAR) invites participants to collaboratively investigate a common concern through the research process. Informed by Kurt Lewin (1946) as well as German sociologist Negt (1984), CUAR is aligned with social-democratic and critical theory ideologies, and works towards the establishment of a “free space” within which the inquiry can take place, that is, “an arena that should enable participants to take part openly and in public and seek to challenge and criticize existing power structures” (Bladt & Nielsen, 2013, p. 376). These authors are not so naïve as to believe that issues of power and hierarchy can be set aside (they cite Foucault widely as well as Lewin), but the process design and facilitation are designed to confront and mitigate against differences in power, and to expand the range of voices and subjectivities brought into such conversations. This process has been put to use in settings as diverse as Danish bread production (Nielsen, 2005), industrial work sites (Olsén, Nielsen, & Nielsen, 1993), nursing homes (Andersen & Bifeldt, 2016), and even a prison (Bladt & Nielsen, 2013).

CUAR can draw upon multiple methods, but the most common is the future creating workshop (FCW), generally attributed to the work of Robert Jungk as a response to what he considered a cult of expert knowledge, suggesting instead “an orientation towards favoring everyday knowledge and a less authoritarian and instrumental world” (Tofteng & Husted, 2014, p. 232). The first phase of the FCW process engages participants in a process of critiquing the current situation. After laying out the factors understood to contribute to the problem as comprehensively as possible, the process shifts to the utopian phase in which participants are invited to imagine “as good as it gets” scenarios and to offer them to the group in as much detail as possible. A contemporary utopian perspective is adopted, in which participants are encouraged to explore multiple possibilities in an attitude of open-ended inquiry and experimentation. Finally, the group is asked to participate in a realization phase in which the constraints and problems that have been identified in the first stage and the “lines of flight” borne from the utopian phase are considered together in developing proposals that are simultaneously aspirational and actionable. Participants are invited to consider which, if any, they wish to contribute their energies towards evolving and actualizing. In the Danish context, this work is often conducted over a series of full-day sessions and the realization phase can be given over to smaller working groups charged with developing strategies, tactics, and timelines for implementation.

As an exemplar of action research, the CUAR tradition helps to deepen our understanding of the mutual constitution of higher education and both presents and futures. The status quo is explicitly problematized. This requires a realistic assessment of the ways in which participants’ individual and collective sense of agency are limited. Critical understanding of “what is” is as important as unleashing the imagination so as to bring radical alternatives within the realm of the possible. It is in this expansion of the imagination and opening up of “feasible utopias” (Barnett, 2013) that CUAR excels. This is not a straightforward matter: as we have argued thus far, our existence within hegemonic structures of power does not prepare us to imagine utopias, nor yet to prefigure alternatives (Amsler, 2015).

Moreover, the success of action research usually depends on a self-identified need for change on the part of the participants involved, as was the case in the aforementioned Danish examples. This is both a key challenge and opportunity when seeking to establish such spaces within higher education settings. Our own forays into connecting with like-minded colleagues and allies indicates that there is significant appetite for change and support for the work of re-imagining higher education worldwide (some examples of this follow). And yet the level of honesty and critique on which action research depends does not always materialize at the institutional level. One challenge to transforming higher education is to claim a space for this kind of open dialogue and to develop strategies for inviting broad participation in these discussions—including that of senior administrators whose roles require them to be more closely aligned with dominant imperatives, and also that of the policy-makers and opinion-leaders who can have such momentous impact on the conditions of higher education, and whose ideological commitments might in fact be neoliberal. Achieving political good-will and voluntary, meaningful participation within CUAR processes across a wide range of often contradictory interests is anything but a simple feat, and may, in fact, be beyond the realm of possibility given existing realities.

This is why it is crucially important to understand action research’s function as a critical utopian, prefigurative orientation; as capable of mobilizing the kinds of “politics of the act” increasingly favoured by broader pro-democracy social movements as more participatory, productive, and empowering than traditional “politics of demand”. From a post-left anarchist perspective, a “politics of the act” is considered less easy to discount, ignore, or control through institutional channels (Nadja, date unknown; Sharpe, 2008). It is seen as a more festive, imaginative, visionary, and creative style of activism (incorporating music, dance, play, and other performative elements), where “instead of griping about what they’re
against, [activists] use their protests to demonstrate what they’re for” (Duncombe, 2002, p.3). This, we argue, is one of the core potential contributions of action research to higher education. Action research enacts a “politics of possibility” that experiments with different notions of agency, power, and knowledge-production, and with models of social change that explicitly link the lived present with the utopian affects of hope and desire.

5. Expanding the range of the possible

Many of us have been relatively successful in creating spaces within the larger context of universities in which we are able to attempt this “politics of possibility” by practicing action research and other radical methodologies for knowledge-production. But we often do so by “flying under the radar”—keeping our heads down, performing the duties of a “real” university professor, while somehow finding time and resources to engage with community partners and nurture students committed to making a change. We have both worked with our colleagues, students, and community partners to create and support action research within our own institutions. The Action Research Center at the University of Cincinnati was founded in 2005 with a mission “to promote social justice and strengthen communities, locally and globally, by advancing research, education, and action through participatory and reflective practices.” ARCIO, the University of Bristol’s center for Action Research and Critical Inquiry in Organisations, was founded in 2010, and represents a commitment to researching in participative and capacity-building ways in organizations and communities, and to developing emancipatory forms of organizing focused on issues of gender, social justice, democracy, inclusivity, activism, and sustainability. These efforts have taken place within what Victor Friedman would call organizational enclaves—semi-protected spaces in which different ways of working are made possible. Drawing upon the work of Kurt Lewin and Pierre Bourdieu, Friedman uses the concepts of field theory in defining enclaves, as constituting “alternative spaces” within a field with rules of the game that are different, and often challenge, those dictated by a larger field of which they are a part” (2011, p. 253). There are two options for such institutional spaces:

On the one hand they may attempt to maintain their separateness, by creating a strong boundary and strongly regulating and restricting the relationship with the larger field. On the other hand, they may attempt to influence the larger field by creating a field in which things can be done differently, thus expanding the range of the possible, and challenging the established rules of the game. (Friedman, 2011, p.253)

The outcome in the first case may help to ensure survival but at the cost of making the space largely irrelevant to the larger institution. The second option, the attempt to reach beyond the enclave in order to achieve organizational transformation or “a major reconfiguration of a field and of the rules of the game” (p. 253), comes at greater risk as this can also lead to institutional push back and even to the shutting down of the spaces by forces threatened by the possibility of such change.

Indeed, in advocating for action research as a means for challenging the hegemony of neoliberal education systems, it is important to acknowledge that treading such a path is likely to involve very real, costly tensions and difficulties for paid, career academics—despite, and even because of, their privilege as insiders. As has been previously noted, attempting to work in non-hierarchical relationships and negotiate shared values, agendas, and objectives with social movement activists and other practitioners and community members is not properly encouraged, supported, or rewarded within academia—especially when one of the explicit aims of working in this way is to reconfigure existing structures of power and privilege. In fact, one of the many ways in which dominant systems and institutions deal with such enclaves is to coopt or colonize them. Firth (2013) points to the tendency within universities to “individualize collective praxis and recuperate their radical otherness for broader, hegemonic (or counter-hegemonic) aims” (p. 257). For a good case in point, consider how the narrative of sustainable development has become mainstream in higher education institutions (see Bessant, Robinson & Ormerod, 2015).

Over the years, we have seen many action research projects and centers created with great energy and enthusiasm flourish for a time and then wither. Reflecting on this trend, Greenwood (2012) observes that action researchers intent on challenging the neoliberal university need to develop “more skill in the analysis of university organizational structures and the goals of academic managers” (p. 121). Greenwood’s recommendation mirrors a critique that can be levelled at prefigurative politics more broadly: to the extent that such approaches privilege participative-democratic processes and self-expressive social forms at the expense of serious political strategizing and the mobilisation of power, leadership and organization, their impact is less significant than desired (Smucker, 2014). From this perspective, prefigurative politics and its more traditional counterpart, strategic politics—the concern of which is to build the formal organizations and political capability to achieve major structural changes in the political, economic, and social orders—are necessary complementarities, and not substitutes for each other. In order to really intervene, challenge, and transform hegemonic structures we must not shy or turn away from the “building and wielding [of] power, leadership, and organization” (Smucker, 2014).

The challenge for action research and other methodological or pedagogical offerings seeking to prefigure radical alternatives is that of critically considering and assertively experimenting with what productive power, organization, and leadership might look like in pursuit of radical higher education reform. How might action research theory and practice help us to work with the tensions raised by attempts to prefigure radical participative-democratic utopias with the necessity to engage seriously and strategically with hegemonic power structures here and now? How might we hold a sense of radical democracy and mutual power both as aspirational ideals and as anticipatory guides to practice? Systemic action research helps us to begin to address these questions through its explicit focus on social change as a systemic dynamic and endeavor.
6. Taking on the task of rebuilding and contributing to systemic change

As Burns (2014) notes, “if action research is to be an effective political tool then it has to move beyond the single local group, team or organisation to work across organisations, networks and partnerships, on multiple sites and at multiple levels” (p. 15). Systemic action research (Burns, 2014) provides us with a vision and means for working at this larger scale, which we believe may help advance the project of dismantling and reclaiming higher education. By creating a space for dialogue among those of us who share these concerns, we can provide mutual support, share resources, and act as critical friends to one another in our efforts to create change. Burns outlines four important characteristics of successful systemic action research projects: They focus on actions which change the overall system dynamic; they are built on multiple inquiries which are networked both horizontally and vertically; the membership in these process is dynamic and follows the emergence of key issues; and finally, they acknowledge the importance of resonance or, as Burns (2014) puts it, “where the energy for change lies within a system” (p. 13).

Expanding on local efforts designed around the principles of action research and other radical methodologies, a first step in the creation of a large-scale systemic action research project would be that of fostering inter-connections and networks across innovative efforts to reframe higher education. This seems a tall order, but in fact, our experience suggests that there are efforts underway around the world where a willingness to connect with others is seen as part of the task of fundamentally reshaping higher education.

Although not specifically action research, the Connected Communities program funded by the Art and Humanities Research Council in the United Kingdom (see Facer & Enright, 2016) includes a number of action research projects and overall reflects many of these aspects of critical utopianism and prefiguration we see as central to our own interest in using action research to transform higher education. Many of the community-university partnerships that are at the core of this funding scheme make particular use of arts-based methods to create space for imagination and creativity in addressing a range of local issues and initiatives, and explicit and sustained efforts have been made to share learning across the various projects.

The Action Research Action Learning (ARAL) conferences hosted by De LaSalle University-Manila provide another example of forward thinking efforts to promote large scale change in higher education (Brydon-Miller, Prudente, & Aguja, 2016). The first of these conferences, held in 2015, featured the Minister of Education of the Philippines, Brother Armin Luistro, who spoke of the importance of university faculty and students engaging in addressing critical educational issues facing the country. The 2016 conference included addresses from colleagues from other South East Asian nations including Myanmar, Malaysia, and Indonesia, with the goal of extending participation to all ASEAN nations in the coming years.

Another effort to transform higher education is being developed by members of the Swedish Participatory Action Research Committee (SPARC). An important goal for SPARC is to establish a national platform for Bildung, education and research that includes a doctoral education program with the label “democratic knowledge and change processes”. The program will be established as a network of universities and folk high schools acting collaboratively. Some courses have already been developed and carried through in cooperation with a number of universities. These courses have been open for doctoral students as well for interested persons coming from the non-academic member organizations. The ambition is that representatives of both the academic members of SPARC and the societal parties or organizations should continue to develop the program in dialogue. A double aim of the SPARC courses is training professional researchers and also involving people who can themselves participate in this kind of research and at the same time engage their organization (Härnström & Holmström, personal communication).

A very recent and exciting initiative is the creation of a network of doctoral students, early career academics, and practitioners called Action Research International Emerging Leaders (ARIEL). This is a conscious attempt on the part of a new generation of action researchers to challenge existing structures by creating vibrant international networks and to mobilize social media and other means of building relationships and creating opportunities for partnership with an explicit focus on extending the realm of the possible, now and into the future.

It is telling to note that the two most long-lived and arguably most successful centers for action research exist outside the confines of universities. The Highlander Research and Education Center in the Appalachian Mountain region of the US was founded in 1932 based on the model of the Danish Folkhighschool Movement. It focused first on labor organizing, later as a key site of the Civil Rights Movement in the US, and more recently as a space for training local and international activists and others around issues of sustainability, environmental justice, and democratic social change. The Society for Participatory Research in Asia (PRIA), based in Delhi, India but active across the region, and really around the world, has worked for more than 30 years to address issues of gender inequality, social exclusion, and economic injustice. Action researchers working within the academy would do well to consider the lessons that might be learned from these two organizations and others like them about the advantages and perspectives available outside the academy.

In fact, these organizations and initiatives do not exist in isolation from one another, but instead already form a strong interconnected set of personal and organizational relationships upon which a more explicit systemic action research process might be engaged. And yet another caveat is important here. One of many helpful comments we received from the reviewers of this article was the suggestion that we might be drawing on an over-optimistic understanding of networks as necessarily emancipatory. This, and the recommended reading, gave us pause for thought. Ball and Junemann (2012), for example, point to the ways in which moves towards network governance in educational reform may mark the beginning of the end of state education, particularly when these networks involve non-state, non-public sector actors and organizations, often held...
together by shared values and discourses centered on the virtues of enterprise and meritocracy, and on “the generic efficacy of ‘market solutions’ to social problems—that is, enterprise in various forms” (p.131). In a similar vein, Ward (2012) defines neo-liberalism as governance through networks, through which hegemonic discourses are replicated and entrenched in wide-ranging social and political action. While the networks we have in mind would by necessity be anti- and counter-neoliberal, the aforementioned critiques raise important considerations, reminding us of the myriad ways in which we are privileged by and complicit in the very dynamics we desire to transform.

This discussion brings us face to face with the normative dimensions of what we are arguing, reminding us of the importance of fostering ongoing critical reflexivity especially on our most deeply held commitments and ideals. With Amsler (2014) we agree that:

[W]e must take responsibility for the specific normative values and objectives of all our projects; remain vigilant about how power works through ostensibly liberatory practices such as dialogue, witnessing and co-operation; and be critically aware of the possibility that such practices can easily be deployed for conservative and repressive ends. (p. 281)

For these reasons, we suggest that it would be most generative to frame systemic action research (and action research more generally) not primarily as a social-democratic, counter-hegemonic set of practices, but as an approach to collaborative activity that is explicitly critical utopian, drawing from this latter tradition a set of orientations that are ongoingly anti-hegemonic, necessarily critical, self-reflexive, pluralistic, and non-recuperative (Firth, 2013; Garforth, 2009). At its best, action research manifests these latter qualities, though like all would-be radical alternatives, it is not immune to cooptation or colonization, and we do not always live up to the high standards we set for ourselves. Nevertheless, it is through aspiring towards and enacting these qualities in the here and now that action research becomes a means of resisting and challenging the capture of the university by neoliberal logics.

In this paper we have attempted to connect more explicitly with the prefigurative and propulsive utopian impulse inherent to much action research. In so doing we have sought to highlight the “practice of simultaneous and ongoing critique and creation” (Firth, 2013, p. 258) underpinning both contemporary utopianism and action research. Firth (2013) reminds us that “critical utopias are critical not only of what exists but are explicitly self-critical and proceed through immanent critique” (p. 258). This is an ongoing challenge for and aspiration of good action research, and is one of the core quality criteria used in the review process for papers submitted to the journal Action Research, of which both the authors were long-time Associate Editors (see Gilhooly & Lee, 2016; Holty, Klein, Cook, & Travers, 2015; Kroeger, Beirne, & Kraus, 2015; Lucio-Villegas, 2016 for recent good examples of this).

7. Why bother? A reconstruction coda

In a recent presentation one of us was describing Burns’ metaphor for systemic action research as being like pushing a rock up a hill, impossible to do alone, but possible with the concerted efforts of many people working together. One of the participants was obviously puzzled by this and asked why not just step out of the way? Let the rock roll back down the hill. Leave the academy to its own sorry future. Put your energies somewhere else, somewhere where they will be welcomed as innovative and appreciated as important contributions. Why be Sisyphus if Zeus hasn’t condemned you? Why? Because despite all of its problems, higher education is still an important site for dialogue, innovation, exploration, and engagement. And it is a site of contention for determining whether or not the future will be one that continues to be constrained by neoliberal perspectives on what constitutes progress or instead is a space for imagining a multitude of visions of creative and compassionate ways forward. Existential threats aside, if our aim is to transform the academy, those of us who identify as action researchers must move outside of our enclaves, using the theory and practice of action research to address the pressing problems facing higher education not just for the sake of action research, nor only to bring about positive change within our own organizations and universities more generally—although this is of critical importance as well—but because higher education has a critical role to play in addressing the problems facing the world today, and can only do so through the kind of fundamental change towards radical democracy and creative expansion of imaginaries that action research can help to create.

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Further reading


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A trend analysis of opportunities and challenges of open and distance learning provision in dual-mode institutions

Bogadi Nage-Sibande & Bantu Lulu Morolong

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A trend analysis of opportunities and challenges of open and distance learning provision in dual-mode institutions

Bogadi Nage-Sibande and Bantu Lulu Morolong

ABSTRACT

Highly skilled manpower is critical for sustainable socio-economic development. However, participation in higher education in Africa continues to be the lowest in the world. Even though some contact universities have adopted the dual-mode strategy to expand access, they continue to enrol fewer students through their open and distance learning (ODL) component. A case study conducted at the University of Botswana to determine possible causes of continued low enrolment through ODL, together with a recent literature review, indicate that within dual-mode universities, ODL experiences challenges related to stigma, resources, planning, implementation and monitoring, resulting in slow growth and low impact. The paper recommends that dual-mode universities need to change their attitude towards their ODL strategy and invest more resources in its development. It also recommends enhancement of parity between ODL and face-to-face provision.

Introduction

Having recognised that highly skilled human resources are critical for innovation and sustainable socio-economic development, nearly all African countries started implementing policies to expand access to tertiary education and training as they gained independence. However, by 2010, data showed that participation in higher education in Africa was less than 10% (Altbach, Reisberg, & Rumble, 2010; UNESCO, 2010). According to the Africa-America Institute (Africa-America Institute, 2015), by 2015 participation in higher education in Africa was 6% of the traditional 18–24 age cohort, and still the lowest in the world. In Botswana, which is a point of reference in this analysis, like in most African countries, provision of higher education and training is regarded as one of the most critical pre-requisites for sustainable development. Although attempts to increase provision of tertiary education have been mainly through traditional face-to-face education, open and distance learning (ODL) has become a very important alternative route.

Some traditionally face-to-face institutions, such as the University of Botswana (UB), have thus adopted ODL as an additional and alternative strategy to expand access. However,
dual-mode universities have long continued to enrol fewer students on their ODL component compared to the face-to-face mode of provision (Nage-Sibande, 2011; Nyerere, 2016; Tshabangu, Matakala, & Zulu, 2013). Nyerere reports that out of a total of 536,000 enrolments in the 12 Kenyan universities surveyed during a study on ODL in Kenya commissioned by the Commonwealth of Learning, only 19,038 were ODL. This seems to suggest that there are challenges with regard to educational provision through ODL within dual-mode university contexts. Noteworthy is the fact that those challenges are being experienced against the backdrop of recorded growth of ODL globally (Chawinga & Zozie, 2016; Kabanda, 2014; Moore & Tait, 2002).

A case study conducted in 2010 revealed that some internal and external challenges faced ODL provision within the UB dual-mode system. The challenges experienced within the UB ODL provision included, among others, unclear and ineffective structures; failure to re-align procedures and processes to accommodate ODL; lack of ODL policies or their lack of implementation where available; low resourcing of ODL leading to perceived poor quality products and services; lack of proper planning; insufficient training for ODL practitioners in important areas such as instructional design and development, appropriate student support services, use of technology to enhance design and facilitation of teaching and learning; and stigma emanating from a general belief that higher education provision through ODL is inferior compared to face-to-face provision (Nage-Sibande, 2011; Tau, 2008). Similar challenges appear to be experienced in other dual-mode institutions and, sometimes, dedicated ODL institutions in the Southern African Development Community (SADC) region and other parts of Africa, as observed by Tshabangu et al. (2013) in Namibia; Bishau and Samkange (2015) in Zimbabwe; Letseka (2015) in South Africa; and Nyerere (2016) in Kenya.

This paper aims conduct a trend analysis of the challenges faced by ODL in dual-mode universities, in order to determine the extent to which it has or has not impacted increased participation in tertiary education. The researchers assess the level of improvement regarding provision and impact of ODL towards increasing participation in tertiary education since it was introduced in dual-mode universities in Southern Africa. The paper further discusses the convergence of ODL and the face-to-face mode of delivery, as well as the likely positive implications of such convergence on both modes of delivery generally and on the dual-mode approach in particular if higher education is to achieve its expected effectiveness in contributing to sustainable development.

**Tertiary education and sustainable socio-economic development**

To achieve sustainable socio-economic development and competitiveness in the knowledge-based global economy, efforts must shift to the production of high quality human resources. Agasisti (2008) as well as Fisher and Scott (2011) observe that availability of sufficient quality and highly skilled human resources is one of the major determinants for socio-economic transformation. It has now been confirmed that successful participation in tertiary level education and training is the key to innovation and high productivity levels (Africa-America Institute, 2015; Bloom, Canning, & Chan, 2005; Fisher & Scott, 2011; Kotecha, Wilson-Strydom, & Fongwa, 2012; Oluwatobi, Olurinola, & Taiwo, 2016). This assertion is against the knowledge that only up to 8.6% of the eligible population is able to access tertiary education (Baah-Boateng, 2016), resulting in comparatively low levels of contribution to socio-economic development, and emancipation of the continent from continued poverty.
The state of continued low participation rates in tertiary education puts more pressure on universities to find innovative ways of expanding access to quality higher education and thereby make a meaning contribution to sustainable socio-economic development. Baah-Boateng (2016) believes that African countries would reap substantial socio-economic benefits if they could increase their investments on improving access to tertiary education and developing strong and relevant curricula for a knowledge-based economy.

As Bloom et al. (2005, p. 16) observed, investing in tertiary education in Africa may accelerate what they refer to as technological catch-up, which in turn would result in technological diffusion and a reduction of the knowledge gap between Africa and the developed world. A more prepared labour market is the one which possesses skills and knowledge enabling it to innovate, as well as compete in a knowledge-based global economic environment. Africa-America Institute (2015) submits that a one-year increase in average tertiary education levels in Africa would eventually yield up to a 12% increase in terms of the gross domestic product. African enrolments more than doubled between 2000 and 2010, from 2.3 to 5.2 million (Africa-America Institute, 2015; McCowan, 2014). However, it was still the lowest in the world with Sub-Saharan Africa recording a gross enrolment ratio of 8.6%, compared to 21.9% in Southeast Asia and 33.1% to about 64.4% in other regions (Baah-Boateng, 2016).

Provision of tertiary education in Africa: a brief overview

Literature indicates that Africa has the youngest population in the world. By 2015, about 50% of this population was made up of young people of an average age of 30 years or less (Africa-America Institute, 2015; Altbach et al., 2010; Baah-Boateng, 2016). This is the population that requires more resources for education, in the face of acute shortages of such resources. The tertiary education system in Sub-Saharan Africa has also been expanding at a high rate, almost twice the global rate, as observed by McCowan (2014) and Africa-America Institute (2015). However, with a faster growing population of the 18–24 age group, the high expansion in tertiary enrolments represented only about 7% of the eligible regional population that needed to undertake tertiary level studies, compared to 29% worldwide (McCowan, 2014). For Sub-Saharan Africa, it has generally been noted that enrolment of young people in higher education is currently below 10%, averaging between 6 and 7% by 2015, compared to the global average of 26% (Africa-America Institute, 2015). The SADC region reported the average regional tertiary enrolment rate as being 6% during the 2011/2012 period (SADC, 2012b). In addition to the growing demand for tertiary education from the 18–24 age group, the number of adults requiring university education and training is also increasing.

The World Bank (2010) acknowledged that complex issues of educational provision contribute to a strain on tertiary institutions. Of the identified areas within the context of the developing world, featuring prominently was the need to increase the amount and quality of research, thus allowing the developing world to select, absorb, and create new knowledge more efficiently (World Bank, 2010). One of the initial reactions to the tertiary education demand pressure by most countries was to expand the resources base for education, such as increasing budgets to ministries of education to facilitate, among others, expansion of the infrastructure. However, it quickly became evident that building more universities or expanding existing infrastructure is unsustainable and fails to adequately address the problems of escalating and diversified demands for access to tertiary education and training.
Since the early 1990s, the total number of higher education students in Africa has tripled, increasing from 2.7 million in 1991 to 9.3 million in 2006 (an average annual rate of 16%), while public resources allocated to current expenditure in that sector only doubled (increasing at an average annual rate of 6% (World Bank, 2010)). Further, the problem of higher education financing is more acute in Africa than in the rest of the world. The Southern African Regional Universities Association (SARUA, cited in Chawinga and Zozie [2016, p. 2]) reported that access to higher education was disturbingly low, as a result of a complex set of challenges. Highlighted among these challenges, those deemed to be directly responsible for the poor status of higher education in Southern Africa include reduced funding by governments to public universities and other institutions of higher learning, which are deemed to be more affordable than private universities; the rise in competition for donor funding amongst private and public universities; increase in the number of students needing university education; and inefficiency in the use of the available resources by higher education institutions (Mnjagila, 2012; Nyerere, 2016; SARUA, cited in Chawinga and Zozie [2016, p. 2]). For Africa generally, and Southern Africa in particular, expansion of the traditional face-to-face institutions is completely outpaced by the growth of the 18–24 age group graduating out of secondary schools and needing opportunities to enrol in university programmes. The challenge is exacerbated by almost equal demands for tertiary education from working adults and even young people who prefer flexible learning environments. As De Wet (2016) observes, it has become crucial for universities to consider and explore other strategies of expanding access to higher education and meeting new learning needs.

**ODL and the face-to-face mode of delivery**

Croft (1992) observes that distance education or ODL occurs in two approaches, or within two types of university set-up. It takes place within dedicated, single-mode distance education universities (open universities) and in dual-mode universities. As the term dual-mode denotes, in a dual-mode university set-up, there are two modes of delivery operating side by side. There is the campus-based face-to-face mode and the ODL mode. The campus-based face-to-face mode depends primarily on the teacher or lecturer and the students being present in the same place at the same time for effective communication, and in order for teaching and learning to take place. The teacher or lecturer is the main source of communication and at the centre of the teaching and learning process. On the other hand, the ODL mode depends primarily on media for effective communication, in order for teaching and learning to take place. The teacher or lecturer, who is in fact a facilitator, does not have to be in the same place at the same time with the students for teaching and learning to take place.

Over the years, this is what has differentiated the two modes. Although the campus-based face-to-face mode has depended on the teacher, ODL has depended on information and communication media, ranging from a simple handwritten letter sent through the post office as far back as the nineteenth century (Demiray & Isman, 2002; Matthews, 1999), through print, radio, and television to the advanced information and communication technologies (ICTs) of the twenty-first century. As media and technology continue to advance, possibilities and opportunities open up for the improvement of the ODL delivery mode.

For many years – in fact centuries – universities have relied on the campus-based face-to-face mode and have understood and respected it as the only effective way of delivering
education and training at university level. This is a deeply entrenched belief system. However, change is inevitable. Social and political environments are no longer the same, means of socio-economic development have changed and populations are no longer small; the world has become one big global village. These and other conditions are not reversible. Therefore, the traditional campus-based face-to-face mode of delivery is finding itself unable to function effectively under this dynamic environment. The very core of campus-based face-to-face delivery, which is the face-to-face teacher-student interaction, is challenged by the sheer numbers that have to receive education from the teacher (Africa-America Institute, 2015; McCowan, 2014). Millions of eligible 18–24-year-olds are out there ready to get into universities.

Adults are also putting pressure on tertiary education providers to provide access. Although overwhelmed campus-based face-to-face universities cannot handle the volume of demand, participation rates remain lowest for Africa, despite the massive expansion of this mode (Baah-Boateng, 2016; Croft, 1992; De Wet, 2016; McCowan, 2014; Oluwatobi et al., 2016; Wangenge-Ouma, 2012). Even as the centrality of tertiary or higher education in sustainable socio-economic development has been confirmed, and some innovative ways of education delivery have been tried with reasonable success (Combrinck, Spamer, & Van Zyl, 2015), Sub-Saharan Africa still records the lowest participation rate in tertiary education, as observed by several researchers (Africa-America Institute, 2015; Baah-Boateng, 2016; De Wet, 2016). This calls for more innovative ways of addressing the access challenge.

Exploring ODL as a strategy to expand access to higher education

It was against the background of this urgent need to find another strategy to expand access that ODL was increasingly regarded as one of the most practical strategies for universities to enhance access to tertiary education (Braimoh, 2010; Chawinga & Zozie, 2016; Letseka, 2015; Nage-Sibande, 2011; Nyerere, 2016; Siaciwena, 2008). By the end of the 1990s, there were strong indications that ODL was becoming more central to the education systems of many countries. Moore and Tait (2002) noted remarkable growth in enrolment with the introduction of distance education programmes in some universities in South Africa (University of Pretoria; University of Port Elizabeth; Rand Afrikaans University; University of KwaZulu Natal). Similar trends were reported in some SADC countries, such as Botswana, Namibia, Malawi, Tanzania, and Zimbabwe (SADC, 2009), where distance education units were introduced within existing traditional tertiary education institutions to widen access, or institutions devoted to the use of ODL to increase access to tertiary education were established. With the establishment of dedicated ODL institutions, such as the former Botswana College of Distance and Open Learning (BOCODOL, now Botswana Open University, the Open University of Tanzania, and Zimbabwe Open University, in addition to the long-established University of South Africa, substantial enrolments have been realised. Therefore, ODL has become a policy option for many African states, as an alternative or complementary mode of learning (Pityana, 2009). Furthermore, the expansion of higher education in Africa has seen a remarkable growth, with ODL becoming one of the most preferred modes of learning. The SADC regional ODL policy framework of 2012 records that enrolments in higher education through ODL programmes had increased substantially, especially in South Africa, Tanzania, Namibia, and Zimbabwe. For example, in South Africa, 38.8% of enrolments at this level were through ODL programmes (SADC, 2012a, p. 14). In Tanzania, Mnjagila (2012)
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reports increased enrolment in ODL from 6709 learners in 2007 to 12,345 in 2012 since the establishment of the National Correspondence Institute, and an enrolment increase from 11,356 learners in 2000 to 68,969 in 2012 since the establishment of the Open University of Tanzania.

For Southern Africa, the SADC approved the Regional ODL Policy Framework, and it reports that ODL at tertiary level is provided by both public and private institutions (SADC, 2012b, p. 14). Further, the SADC (2012a) records that enrolments in higher education through ODL programmes have increased substantially. At the same time, in increasingly market-oriented educational systems, conventional institutions are using ODL as a means of responding to market demands. This has blurred the traditional distinctions between various types of providers, hence bringing in a convergence of the approaches (distance and conventional, public and private institutions (Moore & Tait, 2002).

For Botswana, as is the case in most African countries, ODL is regarded as an important alternative for the expansion of access to higher education for both youth and adults. There is political commitment to the strategy of expanding access to tertiary education through the ODL mode of provision (Ministry of Education, 1994; Ministry of Education & Skills Development, 2008; Tertiary Education Council, 2007). Some traditionally face-to-face institutions in Africa have thus adopted ODL as a strategy to expand access (De Wet, 2016; Nage-Sibande, 2011; Nyerere, 2016; Tau, 2008). A case in point here is UB, which for the past few decades was the premier public higher education institution in Botswana. UB, like other universities, recognizes that an educated nation is one of the key factors to sustainable socio-economic growth, diversification and prosperity. To achieve this goal, the university has positioned itself to provide some of its programmes through ODL to all those who qualify but cannot otherwise join conventional institutions (UB, 2010). UB set itself six strategic objectives or priority areas during its strategic plan period 2009–2016 (UB, 2008b). The first of these priority areas was ‘extending access and participation’ (UB, 2008b, p. 17). To achieve this particular strategic objective, the university planned to expand the annual undergraduate enrolment by 6% for full-time students and 3% for part-time and ODL students, as well as extend the range of offerings and student enrolment at graduate and postgraduate diploma, and master’s degree levels (UB, 2008b).

However, UB continues to expect lower enrolments in ODL compared to the face-to-face mode of provision. Table 1 shows projections for full-time, part-time and ODL enrolments, from 2007 to 2016.

Table 1 indicates student enrolment projections from 2007/2008 to 2015/2016. It seems evident from this table that while UB is committed to expanding access and participation in tertiary education and its conception of how this could be achieved includes using ODL, its enrolment projections still show a bias to achieve this goal through face-to-face enrolments. Although the strategic plan clearly indicates UB’s commitment to expanding access to education, it also demonstrates that emphasis would be to do so mainly through the full-time face-to-face mode, which would grow by 6% annually compared to the 3% growth planned for the ODL mode over an 8-year period to 2016 (UB, 2008b). Table 1 also shows that provision through ODL was to be limited to undergraduate programmes up to 2016 as per the 8-year strategic plan from 2007/2008 to 2015/2016 (UB, 2008a). A focus is made on undergraduate level enrolments, as notably there were no projections for post-graduate diplomas, master’s and PhD level studies by part-time and ODL.
Table 1. Summary of UB student headcount and FTE projections 2007/2008 to 2015/2016 (Adapted from UB, 2008b).

<table>
<thead>
<tr>
<th>Undergraduate</th>
<th>PGDIP/Masters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HC</td>
</tr>
<tr>
<td></td>
<td>FT</td>
</tr>
<tr>
<td>NDP9</td>
<td></td>
</tr>
<tr>
<td>2007/2008</td>
<td>10,781</td>
</tr>
<tr>
<td>2008/2009</td>
<td>11,257</td>
</tr>
<tr>
<td>NDP10</td>
<td></td>
</tr>
<tr>
<td>2009/2010</td>
<td>11,845</td>
</tr>
<tr>
<td>2010/2011</td>
<td>12,418</td>
</tr>
<tr>
<td>2011/2012</td>
<td>13,040</td>
</tr>
<tr>
<td>2012/2013</td>
<td>13,719</td>
</tr>
<tr>
<td>2013/2014</td>
<td>14,464</td>
</tr>
<tr>
<td>2014/2015</td>
<td>15,288</td>
</tr>
<tr>
<td>2015/2016</td>
<td>16,207</td>
</tr>
</tbody>
</table>

Notes: HC = Head count; FTE = Full time equivalent; FT = Full time; PT = Part time; ODL = Open and distance learning.
Figure 1 shows trends of actual enrolment figures, over a 15-year period from the 2000/2001 academic year to the 2014/2015 academic year.

Figure 1 shows actual UB enrolment trends from 2000/2001 to 2014/2015, from full-time as well as part-time and ODL provisions. According to the UB strategic plan to 2016, part-time and ODL was planned to contribute only 3% of the total annual undergraduate enrolment (UB, 2008b). If the plan was to be followed religiously, the figures in Table 2 would be the achieved annual enrolments for ODL during the strategic plan period from 2007/2008 to 2014/2015.

ODL enrolments being tight as a percentage of the face-to-face enrolments, is a serious limiting factor to the growth and contribution that ODL can make with regard to increasing access. As a result of this 3% limitation, it is clear that ODL within the UB dual-mode system made a comparatively insignificant contribution to enrolment, over the 8-year period to 2015 and can be attributed partly to the university’s plans for ODL during that period.

Figure 2 indicates actual enrolment figures for the 2013/2014 academic year according to UB (2015).

The projected total enrolment for full-time face-to-face undergraduate students for the 2013/2014 academic year was 14,464, while for part-time and ODL it was 2875. Evidently, right from the planning stage, the university envisaged less growth for ODL compared to...
the full-time face-to-face mode of provision. According to Figure 2, for the 2013/2014 period the university enrolled 15,671 for the full-time face-to-face mode and 2505 for the part-time and ODL mode. This indicates that while there was improvement in enrolment overall, the university performed above target by about 8% for full-time enrolment, while for part-time and ODL, actual enrolment indicated a shortfall of about 12% on the planned enrolment target. These actuals also show that ODL enrolments were only about 13% of the total UB enrolment and that if the growth trends are anything to go by not much is expected to have changed to date. Although there is demonstrated growth in enrolments for both modes of delivery, there is evidence to suggest that ODL has realised a significantly lower growth trend than the full-time face-to-face mode of delivery. Of interest for this paper are these trends and factors that contribute to this state of affairs in dual-mode institutions.

**Challenges of ODL in dual-mode institutions**

One of the key challenges facing universities is meeting the ever increasing and diversified demands for higher education. Universities which introduce ODL and become dual-mode institutions consider the mode to be one of the strategies through which they can achieve increased enrolments. Experiences from different regions illustrate this point. Even though ODL has the potential to adequately address high and diversified demands for access into tertiary education, several studies, including from Botswana (Nage-Sibande, 2011; Tau, 2008), at SADC regional level (Bishau & Samkange, 2015; Braimoh, 2010; De Wet, 2016; Ndudzo & Nyatanga, 2013; Siaciwena, 2008; Tshabangu et al., 2013), and even further in the African continent (Braimoh, 2010; Jimoh, 2013; Nyerere, 2016; Ohioze, Odishika, Adedeji, Olusanya, & Adesina-Uthman, 2013) indicate that ODL generally enrolls lower figures compared to the face-to-face mode of delivery.

Studies show that ODL generally experiences challenges related to inadequate funding (Nage-Sibande, 2011; Nyerere, 2016), which impacts its development and delivery, and
results in a lack of confidence in its quality and value. The UB study (Nage-Sibande, 2011) also points to internal challenges, such as lack of understanding of the ODL mode by the top management of the hitherto single-mode campus-based face-to-face university. This leads to management’s apparent lack of conviction in ODL’s potential and thus universities end up with limited commitment to its development and support. In the case of UB (Nage-Sibande, 2011), this was evidenced by apparent continued doubt and lack of trust that ODL could handle large numbers of students, and provide quality education and training, many years after UB had adopted the mode as a strategy to avail its programmes to a larger clientele through increased enrolments. UB limited ODL’s contribution to only 3% of the projected annual enrolment, over a period of 8 years from 2008 to 2016 (UB, 2008b). Therefore, the resources that would be allocated to ODL at UB during that 8-year plan period would obviously be influenced by the expected and planned deliverables or targets for the mode. If the university was convinced that ODL could actually deliver more, the targets and the ensuing enabling resources would demonstrate that conviction.

Similar experiences are shared by Muyinda (2011) from Makerere University in Uganda, Letseka (2015) from the University of South Africa, as well as Nyerere (2016) in Kenya. In the case of Uganda, ODL students made up only 20% of the Makerere University student body (Muyinda, 2011). In South Africa, distance education accounted for almost one third of all higher education enrolments (Makoe, cited in Letseka, 2015, p. 7). In Kenya, the Commonwealth of Learning commissioned a comprehensive study conducted by Nyerere (2016) to establish the status of ODL. Twelve universities participated in the study. Very low enrolments were noted on the ODL programmes, compared to the on-campus face-to-face mode of delivery; ODL enrolled only 19,038 students compared to 536,000 on the face-to-face mode, which translates to ODL contributing only about 3.55% of the total enrolment among the 12 universities. Nyerere (2016) identified several quality concerns as possible contributing factors to the low enrolments through ODL, including national and institutional quality assurance policies and perceptions of quality and credibility of ODL in the country. UB expected and planned that ODL’s contribution to the expansion of access to university programmes could only be 3% of the projected annual enrolment and would remain like that over a period of 8 years from 2008 to 2016 (UB, 2008b).

The 2010 UB study (Nage-Sibande, 2011), together with other studies in Africa, indicates that ODL in dual-mode universities generally suffers from lack of policy (Braimoh, 2010; Muyinda, 2011; Nyerere, 2016; Tau, 2008) that gives direction to the way the mode should operate side by side with the campus-based face-to-face mode. Where such policies exist, sometimes there are disparities between policy and practice. In the case of UB, there was a distance education mainstreaming policy. However, ODL continued to be expected to operate under the same conditions as the face-to-face mode (Nage-Sibande, 2011). Once ODL students are subjected to the same regulatory environment and other instruments meant for campus-based face-to-face students, it means their unique needs are not taken into consideration (Tau, 2008). This is bound to adversely affect the performance of the ODL mode in dual-mode institutions.

ODL in most dual-mode universities suffers from inadequate resourcing, no proper and focused planning, no implementation plans and/or lack of efficient and effective monitoring processes at implementation stage (Croft, 1992; Nage-Sibande, Van Vollenhoven, & Hendrikz, 2011; Nyerere, 2016; Siaciwena, 2006; Tau, 2008; Wangenge-Ouma, 2012). Among the issues identified are credibility of the programmes and perception about their quality. Limited or
no appropriate training for the mode is also noted as a major challenge for ODL provision in dual-mode universities (Tau, 2008; Wangenge-Ouma, 2012). The lack of recognition and incentives for the contributions that academics make towards the development, support and enhancement of ODL has been noted as a dent on the growth of ODL. This seems to have served as a demotivating factor for the academic staff of dual-mode universities (Croft, 1992; Tau, 2008). There is no equal treatment and mutual respect (Muyinda, 2011; Tau, 2008; Wangenge-Ouma, 2012) for the two modes of provision that the university would have chosen as its strategic options to deliver tertiary education. This consequently results in the neglect of ODL, allocation of low resources, the mode’s slow growth and low impact on increasing access and participation in higher education. These challenges further lead to stigmatisation and negative attitudes from staff, students and the community, where they perceive ODL to be inferior, compared to the face-to-face mode.

The current literature review corroborates the findings of the 2010 UB case study by Nage-Sibande (2011) and confirms that the concerns it raised then, were similar to concerns raised before (Siacciwena, 2006; Tau, 2008) and are still the same concerns presently experienced with regard to the majority of dual-mode universities in Africa, especially concerns of lack of policy direction and allocation of inadequate resources, which in turn affects the quality of service provision through the ODL strategy (De Wet, 2016; Muyinda, 2011; Nyerere, 2016; Tshabangu et al., 2013). Among the issues mentioned are the quality of ODL programmes and perceptions about their credibility. It is further noted that quality of ODL programmes is grossly affected by inadequate training of staff on ODL methods, procedures and processes as well as inadequate infrastructure due to inadequate funding for the programmes.

The studies consulted also looked at the availability of ICT infrastructure and the level of preparedness for the institutions using ODL to adapt to new ways of integrating technology in the development and delivery of teaching and learning, to meet the needs of the twenty-first century students (Letseka, 2015; Nyerere, 2016). It turns out that generally there are challenges related to both infrastructure development and staff capacity to use available ICTs to enhance the quality of ODL development and delivery. Nyerere (2016) observed that ODL units in dual-mode universities have generally been regarded as income-generating units and thus expected to consume very little resources. It is noted that this expectation has led to inadequate funding for ODL, which presents a major obstacle when it comes to incorporating technology into ODL programmes and has seriously impacted the quality of ODL provision.

The convergence of ODL and face-to-face modes of delivery: implications for the dual-mode approach

ODL currently functions in two ways throughout Africa. On one hand, numerous single-mode open universities have emerged to absorb large numbers of learners, while on the other hand, an increasing number of traditional universities have become dual-mode and offer their programmes through both ODL and face-to-face (Ghosh, Nath, Agarwal, & Nath, 2012). Technological advancements propel the convergence of ODL and the campus-based face-to-face modes. Whereas technology-mediated teaching and learning used to be the prerogative of ODL, the campus-based face-to-face mode is also gradually becoming heavily dependent on technology mediation. Both modes depend on communication technologies
for their effectiveness and convenience. The line between the two is also increasingly being blurred by the advancement of open education resources, eLearning, and the possibilities of low-cost computers (SADC, 2009).

There seem to be inherent challenges in stand-alone single-mode deliveries, whether it is a dedicated ODL mode or a dedicated campus-based face-to-face mode. Each one on its own without the other has inherent challenges. We have seen the campus-based face-to-face mode fail to absorb the large numbers that require university education, primarily because of space limitations, student-teacher ratios, student accommodation and related logistical costs. The changing nature of the university clientele also requires flexible ways of acquiring university education. A sizable percentage of the 18–24-year-olds, who have been the primary target market for the face-to-face universities, have started demanding new innovative and flexible ways of learning, rather than to receive education through the face-to-face mode only. In some campus-based face-to-face universities, this new phenomenon has contributed to a noticeable decline in student enrolments. Universities, therefore, have to come up with workable, effective strategies of addressing today and future needs of the society and of their clientele (Croft, 1992; De Wet, 2016).

On the other hand, single-mode ODL provision also has its own inherent challenges. It has been pointed out that the advancement of online learning has come with its advantages and a fair share of higher cost implications for the mode (Rumble, cited in De Wet, 2016, p. 385). Dependence of the ODL mode on technology also means that a dedicated ODL institution would depend on the level of infrastructure development – first of all, of the country, and secondly, on its own level of resource muscle for a very costly capital outlay, before it can reach the required level of development and delivery effectiveness. That calls for consideration of some innovative strategies, including a blended mode of delivery.

Each mode (i.e., the dedicated face-to-face mode and the dedicated ODL mode) also has inherent advantages. For instance, one of the advantages of the ODL mode is its capacity to enrol large numbers of students and to reach them wherever they are, through the use of media. However, it has been noted that though ODL can enrol large numbers, its throughput rate is very low compared to that of the face-to-face mode (Bunting, Sheppard, Cloete, & Belding, 2010; Letseka, 2015; Lewin & Mawoyo, 2014; Nyerere, 2016). On the other hand, face-to-face mode has the advantage of direct interaction with the student and immediate feedback. That means, each type of the dedicated modes stands to benefit from a blending or partnership of the modes. Therefore, the trend where initially dedicated face-to-face universities seem to be moving towards accommodating ODL ideals to become dual-mode institutions appears to be a strategic move in the right direction (Croft, 1992; Da Costa, 2005). Dedicated open universities too should consider adopting and taking advantage of some of the positive characteristics of the face-to-face mode of delivery. The dual-mode set-up that would result for adoption of one mode within another would benefit from taking the positives from each of the modes and minimising the disadvantages of each, resulting in a major opportunity from the convergence of the two modes. The convergence or the merger of the two modes needs top management commitment and leadership for its successful implementation. The right policy environment followed by implementation, monitoring and evaluation strategies would need to be in place. There would be a need for role clarity and mutual respect for each mode.
Conclusion and recommendations

From the foregoing discussion, it seems fair to conclude that the introduction of ODL has undoubtedly eased pressure on universities to meet the demand of the increasing number of students in need of university education (Chawinga & Zozie, 2016). However, while ODL continues to grow as a means of expanding access and participation in tertiary education, in dual-mode universities it continues to also experience internal and external challenges. This results in its slow growth and an impact that is below its potential. The challenges include weak or no support and commitment for ODL by political and administrative authorities, evidenced mainly through lack of comprehensive ODL policies, and in most cases its glaring absence in development plans. Without policies, it is difficult for universities to develop and implement ODL programmes, even where they make attempts to mainstream it in their delivery processes. According to the SADC (2009), in most dual-mode institutions, ODL implementation is based on the needs of on-campus students and faculty, as ODL is a small, peripheral component.

It is further noted that ODL is structurally under-funded and under-resourced in relation to the multiple functions it is expected to discharge. In dual-mode universities the under-funding is in stark contrast to the better allocations for face-to-face, as discussed in this paper. Bearing in mind the fact that ODL is increasingly becoming heavily dependent on the use of ICTs, accentuating the already challenged situation is poor infrastructural development with regard to the needed facilities. In dual-mode institutions, this lack of development is experienced against the backdrop of existing negative perceptions about ODL. These perceptions are evidenced through scepticism by institutional planners and policy makers about the legitimacy and quality of ODL and its products, and their subsequent reluctance to develop the environment for technology-mediated teaching and learning. As a result of these negative perceptions, face-to-face delivery continues to be preferred, such that even in instances where some resource provisions have been made for ODL, they are under-utilised, leading to the stagnation ODL within the blended learning mode (Muyinda, 2012; SADC, 2009).

When conventional systems and approaches cannot meet the ever-growing needs for tertiary education for sustainable socio-economic development, it is necessary to look for new strategies (De Wet, 2016). Considering the challenges of education and development, both in developing and developed countries, it is not surprising that ODL has often been seen as an important new approach and strategy which can contribute significantly towards resolving challenges of access, quality and equity (Moore & Tait, 2002). Gesinde and Akinwale (cited in Nyerere, 2016, p. 6) note that, in general, ODL has become a policy option for most African states, as it provides opportunities for developing countries to realise their educational goals (Muyinda, 2011). This observation has been shared by several scholars and decision makers in education (Altbach et al., 2010; Ghosh et al., 2012; Molotsi, 2009; Moore & Tait, 2002; Muyinda, 2011; Nyerere, 2016).

However, for higher impact on access and success in higher education, universities need to consider merging the two modes and promoting equivalency, and giving prominence to both ODL and face-to-face. Dual-mode arrangements seem to be the most logical way that universities should plan to embrace, with the convergence of the ODL and face-to-face modes of provision, being positively facilitated by the advancement of ICTs and the changing needs of the twenty-first century student. It is becoming more and more important to
capacitate both academic and administrative staff of the university with knowledge and skills to perform in a blended or dual-mode environment (Nyerere, 2016; Tau, 2008).

Disclosure statement
No potential conflict of interest was reported by the authors.

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<td>An interdisciplinary pilot study conducted in a postgraduate</td>
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<td>programmer in renewable energy (2019)</td>
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Internal quality management in competence-based higher education – An interdisciplinary pilot study conducted in a postgraduate programme in renewable energy

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ABSTRACT

Motivated by the ‘shift from teaching to learning’ in the European Higher Education Area, international researchers, quality assurance agencies and practitioners undertook a joint project in order to develop a new procedure for internal quality management focussing on students’ competences (programme learning outcomes). The procedure consists of three steps: defining competences, screening competences and enhancing competences. An interdisciplinary team conducted a pilot study with the Postgraduate Programme Renewable Energy at Oldenburg University to validate this approach. The results lead to the conclusion that the procedure raises awareness of the study programme’s quality and encourages discussions between students, faculty and academic staff. The most important contribution is to strengthen the study programme’s competence profile.

1. Introduction: shift from teaching to learning

Among other crucial changes, the “shift from teaching to learning” has been a very influential factor for study programmes in the European Higher Education Area in recent decades (Reynolds and Miller, 2013; ESG, 2015). Many higher education institutions amended their study programmes as part of the Bologna Process: they implemented competence-based higher education and made employability their top priority. Their focus shifted from input to output, from teacher-centeredness to student-centeredness and from providing instructions to producing learning (IQM-HE, 2016; Barr and Tagg, 1995).

Despite this paradigm shift, existing quality assurance measures in higher education often still concentrate on teachers, their teaching methods and students’ satisfaction. The typical summative course evaluation serves as an example of this (Bergsmann et al., 2015). Nevertheless, it is evident that these fundamental developments require new evaluation concepts. For this reason, international researchers, quality assurance agencies and practitioners developed an innovative procedure focusing on students’ competences: The IQM Procedure. This procedure first defines intended student competences before assessing perceptions of these competences and finally initiating measures for improvement. Following this approach, the end goal for a study programme is “if the perceived student competences are on the same level as the intended student competences defined in the beginning” (IQM-HE, 2016, p. 12). This approach focuses on programme learning outcomes. In contrast to outcomes on the module level, programme learning outcomes refer to all competences students have achieved at the end of a study programme (IQM-HE, 2016, p. 12).

This pilot study aims to evaluate the quality of the Postgraduate Programme Renewable Energy (PPRE) at Oldenburg University. Specifically, this interdisciplinary project uses a mixed-methods approach to investigate whether PPRE students reach the intended levels of the targeted competences or whether there are gaps between theory and practice. Therefore, our study assesses the impact of the study...
programme (e.g. teaching and learning methods, courses) on the development of students’ competences, and thus also the study programme’s quality. For this reason, the study is motivated by the following research questions:

1. Did students reach the intended competence levels (from the students’ perspective)?
2. Did most students reach the intended competence levels (from faculty members’ perspective)?
3. Did the study programme promote the students’ competences up to the intended competence levels (from the students’ perspective)?

Against this background, we present three central objectives that motivate this paper. An important focus lies on giving an overview about current developments affecting internal quality management and explaining why the higher education field needs a new procedure. Besides that, we will present the IQM Procedure and its transfer into practice. This aspect involves a critical reflection of the procedure itself can promote the communication between different stakeholder groups with regard to the programme’s quality.

Therefore, the article is structured as follows: first, the theoretical background and leading concepts are presented (2). After that, the methodological approach and PPRE as example case are briefly described (3). Finally, the results are presented (4) and discussed (5) and conclusions given (6).

2. Theoretical background: developments affecting internal quality management

Numerous factors and developments influence the application of instruments and processes in internal quality management. The following figure (See Fig. 1) provides an overview of general research developments affecting internal quality management (due to the limitations of this paper, we cannot elaborate on them in detail; for a comprehensive and precise overview, see IQM-HE, 2016, p. 20–44).

The most important areas for developing our procedure were competence and evaluation research.

2.1. Competence research

Several definitions for the understanding, operationalisation and measurement of competences are available (Blömeke et al., 2015). For the purpose of our project and this paper, the term “competence” refers to a comprehensive perspective integrating both a cognitive and a practical aspect (IQM-HE, 2016; Weinert, 2001). This understanding of competence can also be found in Bergsmann et al. (2015). In the IQM Procedure, competences are formulated context-dependently at a medium degree of abstraction.

2.2. Evaluation research

A glance at the literature reveals that evaluation can be defined in many different ways. It is commonly understood to mean the systematic investigation of the utility or the value of a subject. Defining context-sensitive evaluation goals in a heterogeneous team is at the centre of utilization-focused evaluation (IQM-HE, 2016). Evaluation can focus on programmes, projects, products, measures, services, organisations, policies or technologies. According to Cousins and Chouinard (2012), “evaluation is systematic inquiry leading to judgments about program merit, worth and significance, and program decision making” (p. 10).

In the context of higher education, evaluation has played an inherent role in quality management systems for several years. On the one hand, it is used to assess and improve the quality of learning and teaching processes, leading to enhancement and organizational change processes (IQM-HE, 2016). On the other hand, it provides accountability and increased transparency, which is especially important against the background of budgetary restrictions and competitive pressures (DeGEval, 2008; Mittag et al., 2003; Röbken, 2012). It is important to emphasize that a participatory approach to evaluation can ensure that results are meaningful and that all involved stakeholders within the programme (students, faculty, administrative staff and leadership) see the evaluation procedures as a valid tool delivering reliable results for quality enhancement. In Cousins and Chouinard’s (2012) understanding, the term “participatory evaluation” refers to the aim of having trained persons conduct evaluations, involving different stakeholder groups, and focusing “on dimensions of process, rather than on goals or intent” (Cousins & Chouinard, p. 10).

<table>
<thead>
<tr>
<th>European Higher Education Area Developments</th>
<th>Research Developments</th>
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<tr>
<td>- European Standards &amp; Guidelines</td>
<td>- Competence Research</td>
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<td>- Transparency &amp; Recognition Tools</td>
<td>- Evaluation Research</td>
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<td>- External Quality Assurance</td>
<td>- Implementation Research</td>
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**Stakeholders’ needs**

| - Persons in Charge of Quality Management |
| - Faculty                                 |
| - Students                                |
| - Decision-Makers, Employers etc.         |

**Other developments**

| - Domain-Specific Standards & Guidelines |
| - Higher Education Institutions’ Standards & Guidelines |
| - Legal Requirements / National Standards & Guidelines |

Fig. 1. Influences on Internal Quality Management in Higher Education (according to IQM-HE, 2016, p. 20).
3. Methodological approach

In this study, an interdisciplinary team applied and implemented the newly-developed procedure in order to evaluate the quality of PPRE, a competence-based study programme in the field of renewable energy. Methodologically-speaking, we used a mixed methods approach combining quantitative methods for competence screening and qualitative methods for discussing the results. In this section, we will describe the internal quality management procedure in detail.

3.1. Design: internal quality management in competence-based higher education: the new procedure

The IQM Procedure evaluates whether students have achieved certain competences expressed as programme learning outcomes. The procedure consists of three main steps: defining competences, screening competences, and enhancing competences. Fig. 2 graphically depicts the concept and provides an overview of the implementation process and its five phases. By outlining our empirically application of this model, we hope to produce a more complete understanding of competence-based internal quality management. For this reason, we will now describe each individual step of the procedure in detail, making reference to our empirical pilot study.

3.1.1. Preparation phase (February – April 2017)

The general aim of the preparation phase is to inform relevant decision-makers about the deployment of the IQM Procedure and set up an appropriate framework (IQM-HE, 2016). For this reason, we established an Internal Quality Management team (IQM team) with representatives of different stakeholder groups (students, faculty members, quality managers, administrative staff, alumni, representatives of the labour market). To inform and train team members, the quality managers conducted workshops explaining the theoretical background of the IQM Procedure and working through practical exercises related to its application. Last but not least, we discussed and determined what (personnel and time) resources would be dedicated to the project.

3.1.2. Step 1 – Define competences (May – August 2017)

At the heart of the IQM Procedure is a list of competence-oriented learning outcomes for a study programme, known as the competence model. In order to develop a competence model, a higher education institution has to “define competences students should acquire by [the end of] a specific study programme. These competences can be listed e.g. in the curriculum [...]” (IQM-HE, 2016, p. 57). Competence research has identified five quality criteria as central to a well-defined competence model (IQM-HE, 2016):

1. define competence areas
2. use a medium degree of abstraction
3. differentiate between two aspects of competence
4. define competence levels
5. consider the developmental dimension

3.1.3. Step 2 – Screen competences (September – October 2017)

The next step is to screen competences. In this phase, we used two online questionnaires for self-evaluation: one for students and one for teaching faculty members. Our goal with the survey was to answer the question of whether students had reached the intended competence levels and whether the study programme was adequately promoting the
students’ competences. We asked both students and teaching faculty members for their perspectives. The results of the evaluation should show the strengths and weaknesses of the study programme, which can then be tackled by developing quality assurance and quality enhancement measures. Positive results, moreover, can serve as a model of efficient teaching, learning and assessment methods, and can motivate stakeholders to keep up the good work in the future.

### 3.1.4. Step 3 - Enhance competences (in progress)

Quality management often runs the risk of producing big data sets and detailed reports that are then rarely used for quality assurance and quality enhancement. The IQM Procedure for competence-based teaching expends considerable effort on collecting data and producing a thorough report (IQM-HE, 2016). Therefore, we aim to develop and implement concrete measures to enhance the quality of PPRE. The first step towards this goal is for the IQM team to discuss the screening results. We conducted a focus group discussion to consider and examine working theories that could potentially explain the detected weaknesses, focusing on the following aspects: competences, curriculum, learning strategies, teaching methods, exam formats, etc. This involved discussing possible reasons for gaps between the intended competences and the achieved competences (screening results).

### 3.1.5. Reflection phase

The final step of the IQM Procedure is a reflection phase, which completes the process. Coming after developing a competence model, screening competences, and initiating concrete measures based on the results, the aims of the reflection phase are to discuss the implementation process’s success factors and generate ideas for improving the IQM Procedure in the future (IQM-HE, 2016).

### 3.2. Sample: postgraduate programme renewable energy

The University of Oldenburg (Lower Saxony, Germany) has offered the PPRE at the Department of Physics since 1987. The programme is targeted to students with a 6-semester bachelor’s degree in engineering or science and professional experience in the field of energy. The programme includes lectures, seminars and laboratory courses as well as external practical trainings (internships). The PPRE fosters students’ developments of skills and competences in renewable energy, allowing them to start careers in industry, consulting, government, NGOs or research institutes after their graduation. For this reason, the curriculum integrates competence-based teaching and assessment methods such as labs, outdoor experiments, company visits and external trainings at private-sector companies and research institutes. At the end of their studies, students complete a thesis project that draws upon their own interests, their laboratory courses and their external training experiences (University of Oldenburg, 2017a, b).

We conducted a pilot study with the PPRE to validate the newly developed IQM Procedure. In the next section, we provide an overview of the competence model before presenting the study in detail in subsequent sections.

### 3.2.1. Competence model for PPRE

In this section, we present the competence model for PPRE. The competences are expressed as learning outcomes on the programme level, or in other words: what should the students know and be able to do after graduating? We defined 23 competences for the programme. The model (see Table 1) consists of four competence areas, namely:

1. Subject-related competences (6 competences)
2. Scientific and methodological competences (7 competences)
3. Social competences (6 competences)
4. Personal competences (4 competences)

The intended competence levels range from one (low) to five (high) (for a detailed explanation of the different competence levels, see Table 2) and were defined for students at the end of the PPRE. Every competence has defined levels for the cognitive and practical aspects, respectively. Table 3 demonstrates the structure behind the competence model in more detail by applying the five quality criteria mentioned before by way of example (Section 3.1, Step 1).

### 3.3. Data collection: competence screening

The evaluation of students’ competences consisted of a screening of 23 competences grouped into four competence areas based on the Competence Screening Questionnaire for Higher Education (CSQ-HE) (Bergsmann et al., 2017). Using an online questionnaire, students were asked to rate the level of competence they had reached as well as the level to which they perceived competences were taught in the programme: 0 = No knowledge/practical experience; 1 = Threshold; 2 = Foundation; 3 = Interconnection; 4 = Contextualisation; 5 = Expansion; 6 = Generation. In addition, teaching faculty members were asked to estimate the competence levels achieved by the students (75% of the cohort). Students (n = 20) and faculty members (n = 24) were asked to complete the survey via email; participation was on a voluntary basis. The screening took place during the students’ and faculty members’ free time. We used the online survey application LimeSurvey. Table 4 presents the response rate and descriptive statistics.

### 4. Results

Below, we present the results of a descriptive analysis of the students’ competence levels. Generally speaking, there are gaps between...
the intended and reported levels for many competences, but most are no larger than one level.

For simplicity, the results presented below are limited to those discussed most extensively by the IQM team during Step 3 (see 4.1) and which point to concrete measures that can be taken. The graphs show the student perspective on student competences (blue bars), the faculty perspective on student competences (mustard yellow bars) and the student perspective on taught competences (red bars) as well as the intended competence level (yellow lines). All students answered all items (n = 9), while faculty members’ response rates differed by question (n = 7–10). Faculty members were able to skip questions because not every faculty member addresses every competence in his/her courses.

4.1. Practical aspects

The findings reveal numerous gaps, especially with regard to the practical aspects of subject-related competences (see Fig. 3) and scientific and methodological competences (see Fig. 4).

From the students’ perspective, there are gaps between the intended and perceived levels of the practical aspect of every subject-related competence. The gaps are especially high for “explanation and application of principles of different renewable energy conversion processes”, “technical design and assessment of the integration of renewable energy systems into energy supply networks” and “scientific modelling of renewable energy systems”. Gaps are also apparent in the faculty members’ perspective on student competences and the students’ perspective on taught competences, albeit less sizable and less frequent than is the case with the students’ perspective on student competences.

There are also gaps between the intended and reported practical levels of scientific and methodological competences, although they are less severe than for subject-related competences. Nevertheless, gaps exist for every competence except ‘project management’.

4.2. Cognitive aspects

The results show that the students estimated themselves to be at a quite high level with regard to personal competences (see Fig. 5) and social competences (see Fig. 6). This is especially true of the cognitive aspect, where the estimated levels for all competences are higher than intended levels.

The estimated levels for the cognitive aspect of personal competence exceeded the intended levels, especially in students’ evaluations of their own competences. For “responsible working attitude”, “ethical responsibility” and “critical self-reflection with respect to professional competences and limitations,” the reported levels were two levels higher than the intended levels.

The estimated levels for the cognitive aspect of social competences also exceeded the intended levels by one or two levels. The students’ perspective of taught competence is especially high for this competence area and exceeds the intended level by two levels for “communication and work in a team”, “networking/communication addressing different stakeholders” and “negotiation”.

4.3. Differences between the estimations

For some competences, the faculty members’ estimation of the students’ level and the students’ estimation of the taught competence level are equivalent, while the students’ estimate their actual competence level somewhat lower. This is especially true for the subject-related competences (see Figs. 3 and 7).

For the cognitive aspect, students’ estimations of taught competence levels and faculty members’ estimations of student competence levels are the same for every competence except “socio-economic and environmental evaluation of renewable energy technologies and their impact”. For the practical aspect (see Fig. 3), they are on the same level
for every competence except “socio-economic and environmental eva-

luation of renewable energy technologies and their impact” and “sci-

cientific modelling of renewable energy systems”. However, the students’
estimate their own competence at a lower level for both the cognitive
and practical aspects.

5. Discussion and practical implications

The aim of the competence screening was to determine the main
strengths and weaknesses of the study programme in renewable energy
(PPRE) with respect to its competence orientation. Following the IQM
Procedure, we first defined the intended student competences. We then
screened the levels of student competences that had actually been
achieved and compared them to the intended ones. The third step was
for the IQM team to analyse and discuss the screening results and
provide recommendations for quality assurance and quality enhance-
ment. In this section, we first present a summary of the results before
discussing their practical implications in order to illustrate how the
procedure can contribute to a study programme’s quality. Finally, we
reflect on the procedure itself.

Table 3
Sample excerpt from PPRE competence model.

<table>
<thead>
<tr>
<th>Competence Area</th>
<th>Competence</th>
<th>Aspect</th>
<th>Competence Level (after 4th semester)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Subject-related competences</td>
<td>Explanation and application of principles of different renewable energy conversion processes</td>
<td>Cognitive</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Practical</td>
<td>4</td>
</tr>
<tr>
<td>(b) Scientific &amp; methodological competences</td>
<td>Critical and rational evaluation of scientific results, models or concepts</td>
<td>Cognitive</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Practical</td>
<td>4</td>
</tr>
<tr>
<td>(c) Social competences</td>
<td>Communication and work in a diverse team</td>
<td>Cognitive</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Practical</td>
<td>4</td>
</tr>
<tr>
<td>(d) Personal competences</td>
<td>Critical self-reflection with respect to professional competences and limitations</td>
<td>Cognitive</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Practical</td>
<td>4</td>
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</tbody>
</table>

Table 4
Response rate and descriptive statistics for students and faculty.

<table>
<thead>
<tr>
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<th>Faculty</th>
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<tr>
<td>n</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Response rate</td>
<td>45%</td>
<td>42%</td>
</tr>
<tr>
<td>(9 complete answers)</td>
<td>(10 complete answers)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>30.8%</td>
<td>14.3%</td>
</tr>
<tr>
<td>Male</td>
<td>38.5%</td>
<td>28.6%</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>0.0%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Not specified</td>
<td>30.7%</td>
<td>52.3%</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–25</td>
<td>7.7%</td>
<td></td>
</tr>
<tr>
<td>26–30</td>
<td>61.5%</td>
<td></td>
</tr>
<tr>
<td>Not specified</td>
<td>30.8%</td>
<td></td>
</tr>
<tr>
<td>Years of teaching in PPRE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–3</td>
<td>14.3%</td>
<td></td>
</tr>
<tr>
<td>4–6</td>
<td>9.5%</td>
<td></td>
</tr>
<tr>
<td>&gt; 6</td>
<td>23.8%</td>
<td></td>
</tr>
<tr>
<td>Not specified</td>
<td>52.4%</td>
<td></td>
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</tbody>
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Fig. 3. Subject-related competences – practical aspect.
Overall, the screening results reveal a quite diverse picture. Briefly, the central findings of our evaluation are as follows: estimated competence levels are not as high as intended levels, especially for subject-related competences and scientific and methodological competences. This is especially true for the practical aspect of competence. In contrast, students estimate that they are at higher levels than intended in the areas of social and personal competences. This is particularly true of the cognitive aspect, where the estimated levels of all competences were higher than the intended levels. For subject-related competences, faculty members’ estimations of students’ levels and students’ estimations of taught competence levels are the same, while the students’ estimations of their actual competence levels are lower. Last (and most importantly considering the aim of this pilot study), the IQM Procedure in its current form has several points which need to be improved.
Fig. 6. Social competences – cognitive aspect.

Fig. 7. Subject-related competences – cognitive aspect.
These findings need to be discussed in order to correctly understand the results and identify appropriate measures.

The fact that students’ practical competences are not as high as intended for subject-related competences and scientific and methodological competences might indicate that the programme does not sufficiently foster students’ skills in these areas. This leads to the conclusion that the teaching process should place greater emphasis on practical aspects, for example by incorporating more project work and practically-based exercises, in order to unite abstract analyses with hand-on experience. In the context of competence-based higher education, it is important to create an atmosphere in which students are able to put their theoretical knowledge into practice by working on real work/research projects.

Furthermore, the fact that the students estimated their social and personal competences at a quite high level is important to mention. As the PPRE curriculum imparts theoretical knowledge in this area only to a limited extent, it stands to reason that there has been a misjudgement, especially from the students’ perspective. Specifically, they might have conflated practical and theoretical knowledge as well as everyday knowledge and scientific and professional knowledge. To solve this problem, clear and transparent communication of the competence levels is necessary. This should be imparted via a course accompanied by regular reflection on one’s current level of competence. Scales noting where students stood at the beginning of a course/their studies and where they are now can be helpful tools for this. However, competence research shows that competences do not develop linearly, and that effects occur with time lags, not within a short-term time frame. Moreover, reflection on competence development is important not only for individual courses, but also for the study programme as a whole. It could be implemented via a meeting with students and faculty at the beginning of each semester to discuss the present overall objective of the programme and come to a discursive decision. Moreover, it would be useful to train faculty on these issues, as different faculty members might have divergent understandings of the competence “ethical responsibility,” for example, and its scientific and personal meanings.

Moreover, the results for some competences show that faculty members’ estimations of students’ levels and students’ estimations of the taught competence levels are the same, while the students’ estimation of their actual level is lower. This means that there is substantial convergence between the estimated taught level from the students’ perspective and the achieved level from the faculty members’ perspective. This finding strengthens the validity of the formulated competence model, particular for subject-related competences. Nevertheless, the detected gap (students estimate their actual level to be lower than they estimate the taught level) begs the question as to potential reasons: why are students not reaching the taught competence levels? Is the taught level too high? Are the methods appropriate for the desired learning outcomes? It is necessary to discuss these questions with faculty and students. We must ask how all students can be included on an individual and structural basis and why faculty members think students are at a higher level than the students themselves think they are. This concern is connected to the basic problem that students might lack a general overview of the entire range of knowledge within a given competence area, making it difficult for them to assess their own competence levels – how can they be expected to estimate their competence when they do not know what they do not know? Clear communication, described above, can help address this issue as well.

Finally, a discussion of the IQM Procedure itself is warranted. The questionnaire was quite long, meaning that some participants did not finish the questionnaire and did not answer all questions. Therefore, the response rate varies from question to question. In addition, faculty members had difficulty estimating the competences levels of the student body as a whole, as PPRE students are quite diverse. Moreover, as stated above, estimating the levels was difficult, and we cannot be certain that all students and teachers understood the levels correctly and similarly. Thus, providing a more detailed explanation of the procedure and the competence levels might increase the validity of the survey results. The levels are currently presented in textual form. Future surveys might wish to incorporate online tutorials or additional courses to explain the competence levels in more detail.

6. Conclusions

The objectives of this paper were threefold: giving an overview about current developments and explaining the need for a new procedure, presenting such a new procedure and its transfer into practice, and finally yet importantly reflecting the procedure itself and deriving implications and recommendations for the educational field of renewable energy.

Not only current developments and therefore external pressures force higher education institutions to a reversed process of thinking, but first and foremost its transfer into practice shows the innovative potential of the IQM Procedure for competence-based higher education programmes in general. For this reason, we aim to implement the procedure sustainably so that other study programmes and universities can profit from our experiences.

“In the end, the worth of evaluations must be judged by their utility” (Rossi et al., 2004, p. 411): the success of evaluations depends on the practical application and transfer of the findings, information and conclusions. The procedure is not capable of determining students’ competences with perfect precision and conjuring up a perfect, all-embracing study programme – however, this was not our aim. The goal was to screen (and not to measure) competences to gain information as a starting point for discussions between different stakeholders. In addition, competence screening is one instrument of internal quality management besides others. The ability to reflect and critically discuss the results is also an important factor for quality enhancement. We have the impression that our use of the procedure in our study enhanced different stakeholder groups’ sensitivity to quality and quality enhancement.

Moreover, the procedure can spur reflection about a programme’s goals and the cognitive and practical competences intended to be imparted, thereby sharpening the programme’s profile. In addition, it can help to organize communication between and among students, faculty and persons in charge of quality management, thus incorporating voices that are usually not heard. Last but not least, it can initiate smaller changes to improve the programme’s quality.

Therefore, the current study has practical implications. The IQM Procedure provided extensive ‘food for thought’ for all persons involved and offers insights into how students develop competences, laying the foundation for successful employability as well as for personal and professional development.

Especially for the educational field of renewable energy, the procedure presented can lead to a well-founded reflection on the competences, which the programme should impart. In particular for the areas of personal and social competences, two important fields which should not be forgotten when it comes to renewable energy education, the procedure turned out to be invaluable. Based on the present results, we aim to reflect continuously about the extent to which the programme supports the practical aspects adequately and how key competences could be supported more effectively in addition to the professional expertise. A replication of the competence screening will show if the didactical approach has to be adapted.

Some future investments and considerations for renewable energy programmes in general might be to implement the procedure as well (or at least parts of it). Even though it might appear complex and work-filled in the beginning, the outcomes are of high value. Personnel of renewable energy programmes can also contact their local person in charge of quality management to ask for support concerning this endeavour. This could lead to a university-wide dissemination of the procedure and therefore to a mutual exchange of experiences and ideas.
Acknowledgement

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<td>Supercomputers to improve the performance in higher education: A review of the literature (2019)</td>
<td>Computers and Education (article from Elsevier)</td>
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Supercomputers to improve the performance in higher education: A review of the literature

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Keywords: Supercomputing Computational science Training Education Systematic literature review

ABSTRACT

The use of Supercomputers is currently very widespread, constituting an essential component in many fields of science. The interest in the use of high performance computation is increasing in a wider and more diverse population of higher education students, mainly senior undergraduates and postgraduates, because the use of these infrastructures allows learners to improve their skills and the results of their training. For this reason, the demand of courses related to supercomputing increases continuously. In this paper we propose, through a wide review of primary studies, several questions that have been considered as a way of knowing the most widely-used contents in Supercomputing training. We have focused on the factors considered for improving training in Supercomputing, in order to improve the results of researchers in higher education organizations, to identify the limitations of Supercomputing training, and to provide solutions for these limitations. During the search procedure for answering research questions, 1911 studies were considered in the first selection. Through the definition of inclusion and exclusion codes in the results of searching databases, 136 published articles were studied. Finally, using quality criteria, 34 studies were identified as relevant in answering the research questions. Several factors were described, such as the way in which courses related to Supercomputing are organized, the adaptations that are currently being applied in curricula related to the students of these techniques, the use of problem-solving training and the qualification of teachers, among the most relevant ones, as well as several limitations of this type of training and the identification of solutions for these limitations. Data was collected by searching keywords related to Supercomputing training and education in the most important databases used in Computational Science, finding empirical evidence to support the positive effect of High Performance Computers (HPC) on educators and researchers. The implications of this study are: first, it provides a summary of the most relevant factors in improving training, as well as the factors that improve the results through the use of a Supercomputer; and second, it provides the analysis of the limitations found for a better performance of learners and the solutions for these limitations.

1. Introduction

The concept of a Supercomputer is dynamic, and could be described as an instance of the most highly-performing computer...
available at a given time, and which changes as advances in computer science and technology are made (Infante, 1986). A Supercomputer is cutting-edge technology, based on large computing systems providing close to the best currently achievable sustained performance on demanding computational problems (Verschelde, 2012) based on simulations requiring high computing power (Resch, 2005). Supercomputing means running “large” projects or applications (using at least half of the available resources of a “large” system) which cannot be run on small or average sized systems (Jones & Nitzberg, 1999). The processing power of a large number of computers is distributed in the form of computer clusters and a large number of processors are used in close proximity to each other (Seagall, 2013).

The history of supercomputers dates back to the 1940s when the first High-Performance Computers (HPC) were introduced. In the 60s, there was a radical change in the way in which these infrastructures were understood, because of the highly complex simulations used in many projects and their introduction in industry, when the first parallel computers were built (González, Rosillo, Dávila, & Olivera, 2015). During recent decades, educational practice has faced a growing adoption of computer tools for the support of learning processes (Jonassen, 1999; Smeets, 2005). The fast introduction of Supercomputing technologies in education (Bote-Lorenzo et al., 2008) is a key challenge that provides a broader range of opportunities, mainly due to the possibility of managing a high volume of data and information, and has prompted educators and researchers to take a pedagogical view to promote, in the best possible way, teaching and using these infrastructures. All this creates new and critical tasks for the Higher Education System, which require extensive and complete training, using many tools for problem solving (Sung et al., 2003), in the same line of inquiry-based learning, for fostering students’ curiosity and motivation (Specht, Bedek, Duval, & Held, 2013). Such infrastructures can help students, mainly senior undergraduate and postgraduate, to develop their ability, not only computing-competent users, but also non-competent users, contributing to the creation of a new generation of professionals, companies and organizations related to Science and Technology (Bethel et al., 2011). In fact, Supercomputing is considered one of the three pillars, along with theory and laboratory research, on which much of the progress of science and engineering is based. For this reason, students could employ HPC laboratories that have long developed and implemented strategies for making computational tools and analytical technologies available for use by all sectors of society (Bruce et al., 1997). In general, the use of Supercomputers extends into sectors such as Electronics, Telecommunications and Computer Science, Natural Sciences, Computer Science and Engineering, Medicine, Life Sciences, Mechanics, Economics, Social Sciences and Management. Investment in education related to the use of Supercomputers is important in many fields of knowledge, as seen in those described in the UNESCO classification: Engineering (Fabricius, Freundl, Köstler, & Rüde, 2005; Smith, 2014), Economy and Linguistics (Moses & Mariasingam, 2006) and Science (Farina, Anne, & Haas, 2008; Gáziza, Salima, Guldina, & Elena, 2012). Currently, adequate preparation of students is essential to drive innovation and support scientific research. Thus, training for a more highly skilled and knowledgeable workforce, capable of using Supercomputing technology (Coveney, McGuire, Parchment, Kenway, & Parsons, 2012) is much in demand.

The goal of the present paper is to create a visual map of how Supercomputing can improve results obtained by different users. In order to take advantage of Supercomputers, users must know how to adapt their problems to this programming paradigm. Consequently, they must first be taught how to rethink the problems and subsequently be able to try them on a Supercomputer to get better results. When we talk about students we are mainly considering, but not limited to, postgraduate students starting their research career with a Master Thesis or a PhD, as well as postdoc researchers. The study of HPC is an essential part of postgraduate programmes in Computational Science (Zarza, Lugones, Franco, & Luque, 2012). This fulfills the goals of higher education: prepare postgraduate level students for their careers both in academia and industry. This consideration means that Computational Science could be considered in the core area of many postgraduate disciplines where the use of HPC will be essential to solve complex data problems (Alexandrov & Alexandrov, 2015).

After a detailed search of the literature, no review in relation to this topic was found. This demonstrates a lack of attention paid to this field despite the importance these infrastructures have for training future researchers. In order to support the study, we consider that the classification of the results across a field, where the scope has not been described, categorized or evaluated (Hammick, 2005), helps researchers to understand the existing body of knowledge, providing a theoretical foundation for an empirical study, justifying a new contribution to the accumulated knowledge (Levy & Ellist, 2006), which is the essential condition for a field of knowledge to be classified as “scientific” (Hunter, Schmidt, & Jackson, 1982). With the purpose of appreciating the relevance of this study, we have to highlight the importance of the effective literature reviews for the advance of knowledge in general and for the understanding of the breadth of the research on a topic, the empirical evidence, the development of theories or the provision of a conceptual background for a subsequent research, identifying, finally, the topics or research domains that require a deeper analysis (Cooper, 1988) (Leedy & Ormrod, 2001). It is important to promote this study, with the aim of describing how the use of Supercomputers can support learners in the improvement of their specific skills. We also aim to enhance understanding of the core assessment concepts as they occur in this type of training. For the development of the research, a collaboration of a Group of Experts on Scientific Computing was established, charged with clarifying concepts to fulfill the goals established.

The findings will likely be of interest to students, researchers, administrators, and industry leaders as they make, more often, decisions based on computational modelization and intensive calculation. Currently the use of Supercomputers is becoming a key element in the improvement of certain disciplines of higher education. In fact, it is believed that scientists cannot be productive or efficient in terms of global research standards if they are not able to integrate Supercomputing into their research process as a required factor (Emmott & Rison, 2008). In sum, this review synthesizes the relevant literature through training in Supercomputing to provide a comprehensive analysis previously lacking in studies related to this issue. Specifically, the present study poses four research questions: (RQ1): Which are the factors considered as improvements to training in Supercomputing?; (RQ2): How can Supercomputing training improve the results of the students and/or researchers in a high education organization?; (RQ3): What is currently known about the limitations of Supercomputing training? and (RQ4): What are the solutions described for solving the limitations...
related to Supercomputing training?

The remainder of this paper is structured as follows. In section 2, we present the research method for the review of literature, describing research questions, criteria used for inclusion/exclusion, sources of studies, search strategy, data extraction and synthesis of findings. In section 3, we present the results of the proposed systematic study. Finally, in section 4, we present conclusions, limitations and discussions of future research directions.

2. Methodology

The methodology used was the specific systematic review (Kitchenham, Budgen, & Brereton, 2015), based on a taxonomy of literature reviews in education (Cooper, 1988), which is considered true hypothesis-driven research, and in which studies are selected and combined with the use of a pre-defined protocol to reduce subjectivity and the possibility of researcher bias (Anderson et al., 2011; Kitchenham, 2004).

It is necessary to clarify that currently an important part of the training in Supercomputing is taught in specialized intensive courses, mainly as part of other subjects, especially in postgraduate and master's studies. This must be taken into account when analyzing the training and educational processes jointly.

2.1. Research questions

Once the scope of study was established, the research questions were precisely stated to guide the review (Fink, 2010). We specified 4 research questions (RQs) in order to characterize the concept of Supercomputing training and education:

- (RQ1): Which are the factors considered to be improvements to training in Supercomputing?
- (RQ2): How can Supercomputing training improve the results of the students and/or researchers in a high education organization?
- (RQ3): What is currently known about the limitations of Supercomputing training?
- (RQ4): What are the solutions described for solving the limitations related to Supercomputing training?

Addressing the research questions posed above required the collection of several opinions by an Expert Group in Supercomputing formed by the staff of the Technical Department of the Supercomputing Center of Castile and Leon (Spain). Their work was focused on the provision of accurate and unbiased technical information through their experience both in technical tasks, and in the areas of training and education based on Supercomputing applied in several fields of science and technology. Experts simultaneously discussed both strengths and weaknesses of the initial list of proposed research questions, which were ranked with the aim of making the final selection of those considered as adequate for fulfilling the goals of the study.

2.2. Data collection

2.2.1. Search strategy and data sources

The first filter in the search strategy of the investigation consisted of searches from 2005 to 2017. This period was considered because since 2005 relevant studies related to the integration of technology in education and the use of up-to-date hardware and software resources were conducted (Barbara & Donna, 2005; Bomsdorf, 2005; Lim, 2005; Mustafa, 2005; Volman, 2005). This fact could be considered as a key feature for the diffusion of technology in education, and its effectiveness and efficiency for teaching and learning purposes (Gülbahar, 2007). The second filter was the selection of articles written in English (Hammick, Dornan, & Steinert, 2010). The strategy was completed as follow: (1) look for the main search terms; (2) check the keywords in known relevant papers and (3) look for alternate forms of the terms, such as synonyms and relevant keywords. After that, we used Boolean operators OR and AND to add them into the search.

The final decision about the terms used in the search was taken in collaboration with experts in the field of Supercomputing. The following concepts were considered best for searching the responses to every RQ: “High Performance Computing course”, “High Performance Computing training”, “Quality in education” + “High Performance Computing”, “Quality in education” + “Supercomputing”, “Quality training” + “High Performance Computing”, “Quality training” + “Supercomputing”, “Supercomputing course” and “Supercomputing training”. The search of these concepts was done by consulting these Data Bases, which are considered to be the best repositories for searches about computational science: IEEEExplore Digital Library, ACM Digital Library, Elsevier ScienceDirect, Scholar Google and Web of Science. In the end, 1911 papers were retrieved.

2.2.2. Inclusion/exclusion criteria

The second filter was the inclusion and exclusion criteria. It comprises the selection of the most important primary studies from literature.

Initially the selection was 1911 retrieved papers. Later, 1783 articles were excluded, and a third data filter, selecting only those papers included because they addressed educational approaches and/or teaching methods, narrowed the data pool analyzed here to 128 manuscripts, adding another 8 manually searched studies, totaling 136 manuscripts, as the most relevant for answering the research questions (See Fig. 1).

The following list shows the inclusion and exclusion criteria adopted.
Inclusion criteria:

- Studies in which the training is analyzed in depth, in the area of Supercomputing through real case studies and analysis of how it is integrated in the learning environment.
- Studies covering uses of Supercomputing in relation to the training acquired.
- Inclusion of surveys and/or questionnaires on satisfaction of students in their Supercomputing courses.
- Written in English.

Exclusion criteria:

- Scant relationship with Supercomputing (related more to other technologies such as cloud computing or similar).
- Documents that are mere descriptions of the course's content, such as information on timetable, calendar, subjects, etc.
- Documents with superficial descriptions of Supercomputing courses.
- Documents lacking references to training and Supercomputing in the title or in the abstract.
- Papers whose purpose is the development of programs or codes regarding Supercomputing.
- Studies that are repeated in more than one database.
- Duplicate studies with the same results. In this case the most complete was considered.

2.2.3. Search Phases and study selection

As seen in Fig. 1 below, the search is divided into two phases. The search terms are described as:

- **Search Phase 1:** involves individual searching in the electronic databases previously selected for constituting a set of candidate documents. The identification of potentially suitable articles is based on:
  (a) Determination of the set of restrictions relating to the language of publication.
  (b) Definition of sources of primary studies to be obtained.
  (c) Gathering potentially useful titles and abstracts of primary studies obtained.
- **Search Phase 2:** the most relevant articles are gathered in the references lists previously selected, considering other significant documents, for the goal of the study, following these steps:
  (a) Applying criteria for inclusion and exclusion to the titles and abstracts of the articles selected, to identify relevant articles that would provide the data for answering the research questions.
  (b) Extracting articles that could be potentially suitable on the basis of eligible titles and abstracts.
  (c) Assessing the quality of the selection of relevant documents to reach the final selection.
2.2.4. Assessment of item quality

Quality assessment can be performed in several ways considering that the choice of this research was based on a combination of methods due to the scope of the study, both for its technical and educational content. The works used as a basis for the final selection of the items are those specified by Wen, Li, Lin, Hu, and Huang (2012) and the categories established by Kirkpatrick (1967), later revised by education scholars (Harden, Grant, Buckley, & Hart, 1999; Belfield, Bullock, Eynon, & Wall, 2001; Tochel et al., 2009; Hooper, King, Wood, Bilics, & Gupta, 2013) in order to help the assessment of the quality of the articles related to educational interventions.

The analysis of the quality of works assesses the rigor and credibility of the relevant studies, in relation to their capacity and suitability for answering the research questions and their possible impact on the study's conclusions. In order to get the optimal selection of items, 10 quality assessment questions have been defined in the line of the works previously mentioned. The quality assessment criteria are summarized as follows:

- Q1: Is the paper based on research regarding training in supercomputing or is it simply a description of uses of supercomputing as a tool in a field of knowledge?
- Q2: Is there a clear statement of the goals of the research, covering participants' views on the learning experience, its organization, presentation, content, teaching methods, etc.?
- Q3: Was the context of the study well-defined in order to know how the research was being carried out?
- Q4: Was the research design appropriate to address the goals of the research, describing changes in attitudes, beliefs or perceptions as a result of the training in Supercomputing?
- Q5: Is there an adequate description of the transfer of learning to the workplace or willingness of learners to apply new knowledge and skills?
- Q6: Is there a change, due to supercomputing training, in organizational practice?
- Q7: Are the conclusions of the study clear and useful for the object of the research?
- Q8: Are the limitations of the study clearly shown?
- Q9: Is there a clear description of the acquisition of concepts, procedures and principles?
- Q10: Is the study of value for analyzing the benefit for clients/users as a direct result of the educational program?

Each question has only three possible answers: “Yes”, “Partly”, or “No”. These three answers are scored as follows: “Yes” = 1, “Partly” = 0.5, and “No” = 0. For a given study, its quality score is computed by summing up the scores of the answers to the QA questions.

Finally, to guarantee that only the most relevant items had an acceptable quality, a punctuation of every study was conducted, in order to analyze the reliability of the results of the review. The requirement was to receive a rating higher than 5.5 (medium level - Kirkpatrick (1967) and later works based on this one). As a result, 34 of the total 136 articles were accepted (24.98%) and 102 (75.02%) were rejected, as having a quality score below 5 in the second selection phase (see Table 1).

3. Results

In the present study, 34 manuscripts published between 2005 and 2017 (see Fig. 2) have been identified as relevant to answering the questions of the research.

The sources of literature on this research topic are widely spread over a range of many publications with different characteristics (as seen in Table 2), picked out in 27 different publications. The analysis of the information mentioned shows the multidisciplinary nature of the study.

The answers to each of the research questions raised in previous lines are described below:

3.1. RQ1: which are the factors considered that improve supercomputing training?

The factors considered to improve Supercomputing training, extracted from the review, are the following:

- Student explores real scientific problems through hands-on experience (S2, S4, S7, S9, S10, S12, S13, S15, S19, S25, S29), with practical examples of parallel systems and programs (S5, S16, S25), learning the most advanced functionalities of computers,
linking theory with practical problem solving.

b. The content of the courses is normally adapted by including, as a core component, parallelism modules with an easy-to-use high performance cluster system in teaching-oriented computer science curriculum (S1, S27).

c. Supercomputing encourages the exploration of the quantitative characterization of a program’s performance on a variety of platforms (S15, S18).

d. Supercomputing teachers have positive pedagogic characteristics and specific professional competences as scientists and researchers (S11), and are qualified to help the students with complex projects (S17).

e. It is not necessary for all users to have skills in the use of a Supercomputer. In fact, visualization tools help students to understand in depth the nature of particular scientific problems (S21) through the learning of parallel computing (S31), thus approaching the solving of these problems (S16, S21) by manipulating large datasets easily (S20).

Table 2
Selected studies by publication type.

<table>
<thead>
<tr>
<th>Type</th>
<th>Nº of studies</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journals</td>
<td>14</td>
<td>41.18%</td>
</tr>
<tr>
<td>Age (Omaha)</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Biotechnology progress</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>International Journal of Engineering Education</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Journal of Computing Sciences in Colleges</td>
<td>2</td>
<td>5.88%</td>
</tr>
<tr>
<td>Journal of Parallel and Distributed Computing</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Lecture Notes in Computer Science</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Procedia Computer Science</td>
<td>6</td>
<td>17.65%</td>
</tr>
<tr>
<td>Procedia-Social and Behavioral Sciences</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Conferences</td>
<td>15</td>
<td>44.12%</td>
</tr>
<tr>
<td>ACM Transactions on Computing Education (TOCE)</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>ACM annual conference on Innovation and technology in computer science education</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Computational Science-ICCS 2009</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Computing in Science and Engineering</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>DoD HPCMP Users Group Conference</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>5th Global Congress on Engineering Education</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>IEEE Transactions on Education</td>
<td>2</td>
<td>5.88%</td>
</tr>
<tr>
<td>IEEE 26th International Parallel and Distributed Processing Symposium</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>IEEE High Performance Extreme Computing Conference (HPEC ’16)</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>International Symposium Computer Science and Computational Technology</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Second International Conference on Education Technology and Training</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>TeraGrid Conference: Extreme Digital Discovery</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>TG08-TeraGrid Conference</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Workshop on Education for High-Performance Computing</td>
<td>1</td>
<td>2.94%</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>14.71%</td>
</tr>
<tr>
<td>Web resource</td>
<td>5</td>
<td>14.71%</td>
</tr>
</tbody>
</table>
f. Supercomputing training aims to prepare people, to a high standard, across a continuum process to achieve an adequate level of knowledge and proficiency to deal with the largest computing systems available (S2).
g. Training in Supercomputing builds a model-learning methodology that engages students in different types of problem solving (S34).

3.2. RQ2: how can supercomputing training improve the results of the students and/or researchers in a high education organization?

Currently, high performance computing (HPC) is used in higher education to train people on how to solve an array of problems, making it a critical technology in fields such as science, engineering, finance and research and development. Supercomputing may be viewed as the intersection between the frontiers of science and computing, and introduces students to core concepts such as large scale simulation.

In the review, we identified some characteristics of the Supercomputing training, that are directly related to the improvement of the research results in higher education organizations. They are the following:

a. Supercomputing enables users to become competent to work deeper on different problems, closely related with their research fields (S4, S15) through reproducible experiments (S5) which use codes of increasing difficulty to illustrate and experiment through the main programming models (S30).
b. The work with a Supercomputer is cutting-edge in research (S8), and increases the interest in performing independent research work (S29).
c. The availability of network infrastructure, based on a Supercomputing facility (S26, S33), enables the collaboration among research groups distributed geographically (S33), and allows participation in projects of multidisciplinary areas (S8, S19).
d. Supercomputing training leads to a deeper understanding of math and science concepts (S34) that help the researchers in the use of mathematical models (S3, S26, S34) to describe a problem in a specific research field, extract conclusions and evaluate performance on the proposed problem.
e. Courses based on how to run an HPC-related project are an important way of training in Supercomputing (S18), by incorporating experimental components such as models for the applications (S22), simulations and visualizations (S23).
f. Implanting research training using a Supercomputer can strengthen students' enthusiasm for discovery and creativity, broadening their knowledge (S13).
g. As computational capabilities increase, users perform their work faster, finding solutions to more challenging problems, and implementing more research models in the same amount of time (S20).
h. High quality visualization can lead to a new level of understanding of how the data can be partitioned and processed parallelly to simplify the interpretation of the research results (S21). It also represents a mechanism to strengthen the experimental-computational synergy (S3).
i. Numerical simulation afforded by a Supercomputer enables the study of complex systems and natural phenomena that would be too expensive, or even impossible to study by direct experimentation (S14).
j. Simulations and data design practice generate large volumes of data (S34) and prepare students for future research in the area of very large database systems (S1), covering a variety of applications (S22).
k. Supercomputing contributes to the invention of new tools and new philosophies of work which enhance learning about computing (S9).
l. Knowledge in Supercomputing encourages the designing of efficient programs that provide students with a crucial understanding regarding the importance of underlying algorithms in the implementation of larger programs (S9).
m. Feedback on the performance of the students in a Supercomputing course helps guide the training, maximizing the time that they use for their research, which is highly desirable on a research project due to its importance (S17).

3.3. RQ3: what is currently known about the limitations in supercomputing training?

Considering the response of the research questions of this study, we identified some limitations that must be mentioned. The findings obtained in RQ1 and RQ2 show a wide description of the different roles of Supercomputer uses (students, teachers, experts, researchers, etc.), access to these infrastructures and the way of developing courses. With these in mind as well as better organization and understanding of the information, the limitations were grouped into four types (see Table 3), depending on the dimension involved: Students, Teachers, HPC infrastructures and Methodology and development of the training.

3.4. RQ4: what are the described solutions for solving the described limitations in relation to the training in supercomputing?

Following the same structure of the previous question, for a better organization and understanding of the information, the solutions of the limitations were grouped into four types (see Table 4), depending on the dimension involved: Students, Teachers, HPC infrastructures and Methodology and development of the training. Considering the response of the research questions of this study, we identified some limitations that must be mentioned in every type.
Table 3  
Limitations in supercomputing training.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Limitations</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>Insufficient educational background, with different degrees and/or specialization, mainly in programming languages.</td>
<td>S4, 5, 9, S17, S23, S26, S28</td>
</tr>
<tr>
<td></td>
<td>Constraints of the typical high school curriculum, in relation with Supercomputing.</td>
<td>S12, S17, S25</td>
</tr>
<tr>
<td></td>
<td>Lack of basic skills for designing, implementing and operating in Supercomputing environments, especially for developing parallel software applications to achieve best efficiency, performance and scalability.</td>
<td>S1, S15, S29</td>
</tr>
<tr>
<td></td>
<td>Need of mathematical sophistication to complete an advanced Supercomputing course to use mathematical models properly.</td>
<td>S32</td>
</tr>
<tr>
<td>Teachers</td>
<td>Substantial effort and dedication for a successful deployment of the tools in order for the course to be properly prepared, which means less time to prepare the content.</td>
<td>S13</td>
</tr>
<tr>
<td></td>
<td>Need of complementing the training of the teachers, especially in parallel computing, through the engagement of experts.</td>
<td>S2, S11</td>
</tr>
<tr>
<td></td>
<td>Lack of experience in the field of HPC.</td>
<td>S1</td>
</tr>
<tr>
<td>HPC Infrastructure</td>
<td>Difficulty for the recruitment of enough tutors to maintain a reasonable tutor/trainee ratio.</td>
<td>S2</td>
</tr>
<tr>
<td></td>
<td>Rapid changes in the systems and software currently and in the coming years, with a continuous growth in the volume of data managed.</td>
<td>S2, S17, S18, S20, S27, S29</td>
</tr>
<tr>
<td>Methodology and development of the training</td>
<td>Need to predict the utility and relevance of forthcoming technologies in both the short and the long term.</td>
<td>S28</td>
</tr>
<tr>
<td></td>
<td>Low availability of Supercomputing facilities due to the high costs.</td>
<td>S8</td>
</tr>
<tr>
<td></td>
<td>Lack of funds to purchase expensive parallel computers.</td>
<td>S29, S31</td>
</tr>
<tr>
<td></td>
<td>Users are not adequately served by their local Supercomputing Center.</td>
<td>S1, S28</td>
</tr>
<tr>
<td></td>
<td>Difficulties in coordinating the Supercomputing sites of the diverse training facilities to handle a large number of inexperienced students.</td>
<td>S2, S30</td>
</tr>
<tr>
<td></td>
<td>Problems with the use of the interface of the operating system.</td>
<td>S13</td>
</tr>
<tr>
<td></td>
<td>Lack of use of on-line learning technologies.</td>
<td>S2</td>
</tr>
<tr>
<td></td>
<td>Existing training material is inadequate for training delivery.</td>
<td>S2, S20, S28</td>
</tr>
<tr>
<td></td>
<td>Need to focus the undergraduate courses on the skills for improving training in Supercomputing technology in nearly all areas.</td>
<td>S1, S17, S28</td>
</tr>
<tr>
<td></td>
<td>Time constraint, both for students and teachers, mainly for the implementation of numerical algorithms.</td>
<td>S13, S20, S25, S28, S30</td>
</tr>
<tr>
<td></td>
<td>Lack of training of writing programs for Supercomputing machines to see clearly the effects of parallel programming.</td>
<td>S24, S25</td>
</tr>
<tr>
<td></td>
<td>Necessity to effectively employ massively parallel high-performance computing machines in scientific computations.</td>
<td>S29</td>
</tr>
</tbody>
</table>

4. Discussion

Our findings suggest that including Supercomputers in learning processes has provided a wide range of new opportunities for learners, mainly due to the improvement in the quality of training obtained, which provides better results in the practical cases through real-life situations. At the same time, the study identifies the learning needs and devises strategies of how to meet those needs. However, as seen in the previous section, there is a lack in the literature concerning the degree in which the use of a Supercomputer impacts the final result of a research project. In order to find out how the characteristics of this infrastructure can improve the learning process pedagogically, a systematic effort and more empirical studies are needed, as seen in other analyses in relation with the use of technology in learning (Mikropoulos & Natsis, 2011). Although research pointed out the need for better previous training of the students, this review provides other actions to be deployed, such as new methods of teaching or the need of an easier access to the Supercomputing infrastructures.

In order to deepen the research, the study implemented several steps to support the quality of the results of the analysis done. The interpretation of the final results can be generalized as goals, actions and strategies for teaching and guiding learners in their learning process, taking into consideration that without a critical and rational discussion about the opportunities of new technologies in education, little progress can be made towards a real debate about the impact of these infrastructures.

4.1. Outcomes

The main outcomes which respond to the RQ raised at the beginning of this study are summarized below.

- (RQ1) The factors considered for improving training in Supercomputing show that the most relevant one is the way in which the course is organized and the adaptations that are currently being applied in the curricula related to the students of these techniques, using examples with a problem-based model, showing how to solve real problems with access to a Supercomputer. Another important factor is the qualification of teachers, essential for a better performance, and finally the use of tools, as visualization facilities that provide an easy understanding for all the students.
- (RQ2) As a conclusion to this question, it is found that the possibility of working in a network of multidisciplinary research groups clearly enhances the performance of the researchers. The contacts provided by these groups open the possibility of participating in
Table 4
Solutions to limitations in supercomputing training.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Solutions to Limitations</th>
<th>References</th>
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<tbody>
<tr>
<td>Students</td>
<td>Implementation of a wide number of introductory courses of Supercomputing for students without a computational background.</td>
<td>S9, S19, S32</td>
</tr>
<tr>
<td></td>
<td>Reformulation of the curriculum system (including parallel computing topics at early state), teaching methods, type of examination and the model of theoretical courses.</td>
<td>S13, S14, S29</td>
</tr>
<tr>
<td></td>
<td>Attracting students in several ways such as summer workshops, using robots, etc.</td>
<td>S10</td>
</tr>
<tr>
<td>Teachers</td>
<td>Increase in the number of teaching assistant contact hours.</td>
<td>S19</td>
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<td></td>
<td>Adequate teaching environment for providing outlines of the basic vocabulary and concepts related to Supercomputing.</td>
<td>S20</td>
</tr>
<tr>
<td></td>
<td>Use of face-to-face training sessions delivered by experts in every field, which means widespread acceptance, and the improvement of the transfer of knowledge.</td>
<td>S2, S28</td>
</tr>
<tr>
<td></td>
<td>Team work environment in Supercomputing training, for a better exchange of ideas with the coordination of the tutor.</td>
<td>S7, S8, S25, S27, S31</td>
</tr>
<tr>
<td>HPC Infrastructure</td>
<td>Transmission of the skills to perform repeatability experiments.</td>
<td>S5</td>
</tr>
<tr>
<td></td>
<td>Supercomputing systems tend to be shared by multiple users, interacting remotely, representing a solution of the high cost of using a Supercomputer.</td>
<td>S20, S29</td>
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<td></td>
<td>Implementation of open source software and operating systems to reduce the cost and for an easy use, providing a user-friendly interface.</td>
<td>S1, S6, S12, S30</td>
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<td></td>
<td>New and easy-to-use software makes computer simulation accessible to a wider group of people.</td>
<td>S34</td>
</tr>
<tr>
<td></td>
<td>Use of optimal and feasible high computing power with relatively low cost, through alternatives to Supercomputing platforms, such as the cluster-based computing system for its flexibility.</td>
<td>S1</td>
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<td></td>
<td>Use of grid technology in the educational environment helps the students in the use of complex models and simulations.</td>
<td>S22, S30</td>
</tr>
<tr>
<td>Methodology and development of the training</td>
<td>The progress of networks technologies has permitted the use of local networks of enterprises and training rooms for parallel computing.</td>
<td>S11</td>
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<tr>
<td></td>
<td>Development of a timely and quality ‘study pack’ of materials, such as tutorials, textbooks via web, user guides, electronic slides, interactive computer-based courses, books and journals, that teach Supercomputing in a rapidly changing environment.</td>
<td>S2, S6, S7, S8, S9, S12, S13, S14, S17, S18, S25, S28, S30</td>
</tr>
<tr>
<td></td>
<td>Use of pedagogical tools which enhance trust in students’ work.</td>
<td>S5</td>
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<tr>
<td></td>
<td>Provision of an easy access to a real Supercomputing system inspires and motivates students, giving the opportunity to implement algorithms using different architectures and parallel-programming models, which enable students to make objective performance comparisons.</td>
<td>S12, S20, S30</td>
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<td></td>
<td>Collaboration of Supercomputing Centers in the provision of a platform to access the resources easily, and with the support from different institutions, which ensure that training needs and expectations are met for all users, without interference to the research activities of the supercomputing center.</td>
<td>S2, S7, S10, S14, S28, S30</td>
</tr>
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<td></td>
<td>Wide variety of training programs in Supercomputing with different sets of subjects offered to complement knowledge, according to the expected skills at the conclusion of the training program.</td>
<td>S14, S26</td>
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<td>Benchmarking to improve training, by describing a taxonomy for general benchmark experiments, and accessing (usually for benchmarking comparisons) an even wider class of machines.</td>
<td>S5, S8, S14</td>
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<td></td>
<td>Development of research-oriented teaching method, to achieve a superior teaching quality, and to involve students in the research oriented learning, based on a high-performance computing research-oriented learning environment.</td>
<td>S13, S31</td>
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research and development projects, using techniques of numerical simulation, which contribute to solving the processes on which research is based in a short period of time, and allowing a better interpretation of the results.

- (RQ3) The limitations of the study are mainly focused on the insufficient background of the students in certain specialties. This is caused by many factors such as constraints in the curriculum, rapid changes in this field, sophistication of the mathematical models, and even other questions such as a general lack of experience in the field of Supercomputing, which affects questions such as recruitment of teachers, use of Supercomputing facilities, and the time constraints of the courses. Another important limitation is Supercomputing infrastructure cost, which causes difficulties in accessing Supercomputing resources.

- (RQ4) The solutions proposed for the described limitations in the study focus on the improvement of training of students previous to a Supercomputing course in order to have the basic knowledge to attend the course, with complete and updated material and with adequate access to a Supercomputer.
4.2. Limitations

During the course of the literature review, the greatest difficulty encountered was the heterogeneity in the type of articles, such as in content related with the typology of training. As seen in the answer to the RQs and also in the study of the courses, it is necessary to improve some basic aspects for an optimal training, as provision of previous basic training for those students who, despite being mainly but not limited to postgraduates, have an insufficient background in Supercomputing techniques, the adequate qualification of teachers and a wider use of Supercomputing facilities. Our hope is also that the present study will encourage researchers and institutions in general to contribute to the development of agreements which address the challenges of using a Supercomputer as part of the fundamental knowledge for scientific uses through the use of a real HPC infrastructure.

5. Conclusions and future work

This study provides yields two main outcomes in relation to the state-of-art of Supercomputing training. First, it provides a summary of the most relevant factors in improving training, as well as the factors that improve the results through the use of a Supercomputer. The second outcome of the review is the analysis of the limitations found of a better performance of learners and the solutions for these limitations. The intention of this instrument is to allow the design of activities and the deployment of strategies which gradually foster the different components of training through the use of these infrastructures. Moreover, it helps to raise awareness of the potential of Supercomputers to enable learners’ a best performance.

From a practical perspective the results of this study will allow detecting the main problems or gaps in Supercomputing learning initiatives by taking into account our research questions. With this information it is possible to define learning plans better and more accurately, thus helping to increase both researchers’ and advanced students’ performance.

Finally, future work should be focused, comprehensively and simultaneously, on analyzing new methods and tools to evaluate the quality of Supercomputing training, and on exploring a full range of fields where the use of Supercomputers will be helpful in enhancing the results of research projects. As seen in the study, personalized introductory lessons according to the previous knowledge of every student, the possibility of working online through new scientific networks of communications, the use of real Supercomputers for optimizing workflows, and more practical sessions should be the key factors of courses related to the success of Supercomputing training in the future.

Funding

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Appendix A. Bibliographic details of the papers that were assessed using quality assessment criteria.


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<td>Performance-based resource allocation for higher education institutions in China (2019)</td>
<td>Socio-Economic Planning Sciences (article from Elsevier)</td>
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Performance-based resource allocation for higher education institutions in China

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Keywords:
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ABSTRACT

How to allocate limited resource to higher education institutions has always been a critical problem with significant social and economic relevance. Researchers and educational administrators have long proposed that resource allocation should be linked to performance. In this paper, we develop a performance-based method for a central planner to allocate research funding to different universities to better stimulate the research output. The method builds on existing works on resource allocation via efficiency analysis. The method takes multiple dimensions of research performance into account, including number of publications, number of patents, and revenue from knowledge transfer. We apply the method to a set of 64 major universities in China based on performance in 2014–2016. The application is particularly pertinent at the moment, since the Chinese government is developing a new funding program called the “double first-class” plan, which features performance-based funding as a central pillar of government funding.

1. Introduction

In the past several decades, many countries have increasingly embraced the performance-based funding (PBF) method to allocate resources to higher education institutions [1–4], in response to mounting public pressure on efficient use of taxpayers’ money and escalating demand for accountability. In the United States (US), PBF is steadily gaining ground at the state level with 22 states adopting or in the process of adopting it as of 2013 [5]. In the European Union (EU), PBF has become a well-established standard practice in many countries. The United Kingdom (UK) has been disbursing block research funds to universities based on periodic assessment of academic performance since 1980s [6]. Some other EU countries (Belgium, Denmark, Finland, Norway and Portugal) have followed the “Norwegian Model” to allocate a proportion of government fund based on publication outputs [7].

Although the effectiveness of PBF has been validated in many countries, its use in China is limited. Like most of the countries where public universities play a dominant role in higher education, the government in China has a strong control on resource allocation to higher education institutions. Financial allocation from the government is the most important source of funding for Chinese universities, accounting for 55% of a university’s total funding on average [8]. A significant portion of government fund is distributed through special funding programs targeting at a small set of universities. The most notable funding programs are the “211 Project” and the “985 Project”. The 211 Project, initiated in 1995 by Ministry of Education of China, is a multi-year funding program designed to support selected universities to attain world-class research and teaching quality. As of 2011, there are 116 universities admitted into the program. The 985 Project, launched in 1998, is a similar but more selective and well-funded program compared to the 211 Project. The program only involves nine top universities at the beginning and gradually expands to 39 universities by 2011. Despite that special funding programs like the 211 Project and the 985 Project are credited with greatly enhancing the research capability of Chinese universities, there is widespread criticism on those programs [9]. The criticism focuses on three aspects, i.e., disparity, inefficiency, and lack of performance assessment for participating universities. From 2009 to 2013, more than 72% of government research fund is given to the 116 universities in 211 Project and 985 Project, while the remaining around 2000 universities share the rest 28% [10]. There is also great disparity within the participating universities. The president of Guizhou University, a university in the 211 Project, complains that financial support to his university in the past thirty years is less than the fund allocated to the two most prestigious universities Tsinghua and Peking in a single year [11]. Meanwhile, efficiency of the programs is also under attack. Among the universities involved in the 985 Project, there is evidence that lower tier universities which received less financial support, improved faster in research output than the most prestigious universities, which received the biggest support [9]. It is also found that [11], “some universities that are enlisted in these projects do not make good use of the research funds they receive and that some even misappropriate research money.”
Finally, while the programs generally request performance assessment for participating universities, in practice the assessment results do not carry much weight in fund allocation.

Realizing the predicament of the existing funding programs, Chinese government has decided to pursue a major reform and institute a new funding system. Officially designated as the “double first-class” plan and unveiled in 2015, the new funding system aims to build both world-class universities and world-class disciplines. It is widely believed that in the future, the plan will assume a dominant role in government funding for higher education in China, and will have a profound and lasting impact on Chinese universities. In response to the criticism on 211 and 985 Projects, the double first-class plan introduces PBF as one of the central pillars of the reform. The plan asserts that government funding for selected universities will be dynamically adjusted conditionally on performance. It emphasizes that bad performers should be penalized with reduced support and even kicked out of the program. The implementation details on performance criteria and fund allocation method have not been disclosed yet.

In light of the transition of the Chinese higher education system, we develop a performance-based resource allocation model based on efficiency analysis. As one of the first steps to meet the challenges, administrators and policymakers need to measure the performance of the universities. For this purpose, efficiency assessment by data envelopment analysis (DEA) has proven to be a useful approach. DEA is a mathematical programming approach to benchmark the performance of a group of production units, dubbed as the decision making units (DMUs) in the DEA nomenclature [12]. The application of DEA to university assessment has become an important and appealing research topic over the years in fields such as management, education economics, and public policy [10,13,14]. The strengths of DEA lie in two aspects. First, DEA is a non-parametric method and thus does not assume any functional forms for the production process of the universities. Second, the capability of handling multiple inputs and outputs makes DEA an appealing assessment tool, because a university naturally transforms multiple inputs such as R&D staffs, faculties, postgraduates and research funding, into multiple outputs such as research papers, patents, and knowledge transfer. DEA identifies the bad performers which should be targeted for further improvement, and the good performers which should serve as role models for other institutions. The efficiency assessment results are employed as the basis for resource allocation. The central planner maximizes the total outputs of all universities by adjusting the distribution of research fund, subject to constraints on availability of resource, range of input and output adjustment, and change of individual university’s efficiency. We demonstrate the effectiveness of the method by applying it to a group of 64 Chinese universities based on their performance over 2014–2016.

The rest of the paper is structured as follows. Section 2 reviews relevant literature. Section 3 presents the models. Section 4 describes the data and variables. Section 5 presents the results. Section 6 discusses policy implications and potential extensions.

2. Literature review

Conceptually, our study builds on the intersection of three streams of literature, i.e., assessment of university performance, the relationship between funding and performance, and performance-based resource allocation. Method-wise, our study is related to the literature about application of DEA to university assessment.

Performance assessment constitutes the foundation of resource allocation in our paper. A great amount of research has been devoted to the study of university assessment [13,15–21], which generally falls into the domain of education economics. These assessment studies have proposed various university performance measures from different perspectives, including teaching [13,15,16,21], research [18–19] and sustainability [20]. The most commonly used measures to capture the research output include the number of research publications [3,20], research capability rating [16], citation or impact of publications [17,22], number of patents [23], and knowledge transfer activities [23–25]. The generation of research output requires various inputs such as professors, graduate students and funding. Our paper uses the DEA method to integrate multiple inputs and multiple outputs into consideration simultaneously to construct holistic performance measures. The application of DEA to the assessment of higher education institutions has already received considerable attention in prior research. For example, Ahn et al. [26] demonstrate the effectiveness of DEA assessment and discuss its advantage over traditional approaches. Flegg et al. [27] apply the method to British universities, and analyze the causes of efficiency change by developing and decomposing the DEA-based Malmquist index. Thanassoulis et al. [28] use DEA to study the cost structure, efficiency and productivity of universities in England, and estimate the expansion potential of the universities. Johnes and Johnes [29] extend DEA approach to assess the research performance of UK economics departments. De Witte and López-Torres [30] and Johnes [31] provide detailed reviews on the topic. While a substantial bulk of studies have employed DEA to analyze university performance, to the best of our knowledge, no prior research has gone further to study the resource allocation problem. Our research contributes to the literature by demonstrating the applicability of DEA-based resource allocation to higher education institutions.

Resource allocation in the public sector is always a problem of great importance and has been studied extensively [14,32,33]. This problem is especially relevant when a central planner exists and is charged with the allocation decision for a group of organizations. Various methods have been proposed, such as dynamic programming [34], goal programming [35], simulation [36], and of particular relevance to this study, DEA efficiency analysis [37–39]. The objective of these methods is either to minimize the total quantity of certain inputs or to maximize the total quantity of certain outputs over all the production units. The allocation decision may be constrained by capacity, budget and requirement of the distribution of inputs/outputs [37]. Within the literature on DEA-based resource allocation, there are two popular types of approaches. The first type of approach solves a single linear programming problem to determine the distribution of inputs and outputs without explicitly computing the efficiency for each organization [38]. The second type of approach follows a two-step procedure, where the efficiencies are derived in the first step and used as the basis of allocation in the second step [37]. Both approaches have been extensively applied in various situations [40–42]. Our research follows the two-step procedure as in Ref. [37].

A lot of empirical studies have investigated the impact of funding on research performance among Chinese universities [3,9,10,43,44]. For example, Yaisawarng and Ng [10] find that the 211 Project, a prominent funding program in China, has successfully boosted the research capabilities of universities admitted into the program. Further, Zhang et al. [9] find the impact of funding may not be homogeneous. Specifically, after the launch of the 985 Project, the most significant funding program in China, publications from lower tier universities in the program grow at a faster rate than the top universities. These studies are generally descriptive in nature, aiming at identifying the effect of funding on research. Our research is prescriptive in the sense that we aim to optimize the resource allocation scheme such that the most desirable research performance can be achieved.

3. Models

We develop the method in the spirit of [37], where the performance-based funding problem can be divided into two sub-problems, performance assessment and resource allocation. The latter model draws on the result of the first model. The two models are described below.
3.1. Performance assessment model

The generation of research outputs is a complex process that involves multiple factors. The most widely used assessment methods are usually based on performance indicators, such as number of publication and number of citations. The performance indicators, while easy to understand and derive, are criticized for “their inability to capture the interplay among various inputs and outputs” [13]. A desirable assessment method should be able to combine relevant inputs and outputs to form a coherent and unified measure. DEA offers an adequate approach for this purpose [26]. As a nonparametric mathematical programming approach, DEA can benchmark the performance of a group of production units labeled as DMUs in transforming multiple inputs into multiple outputs [12]. Using the inputs and outputs of the units, DEA constructs an efficiency frontier by fitting piecewise linear segments to enclose all the units. For each unit, DEA computes a score bounded between 0 and 1 to capture the unit’s efficiency (e.g., distance) relative to the frontier. A score of unity means the DMU is on the frontier and thus efficient, whereas a score less than unity indicates inefficiency. Compared to regression methods such as stochastic frontier approach (SFA) [45], DEA imposes no restrictions on the functional form of production and thus is especially adequate when the production process is complex.

Various DEA models have been proposed based on returns-to-scale and measurement orientation. In this study, we use the variable returns-to-scale (VRS) model, rather than the constant returns-to-scale (CRS) model. This is because the CRS assumption, though convenient in certain scenarios, is too rigid for many real-life processes. As pointed out in Ref. [25], “in most sectors the true technology experiences variable returns-to-scale”. Therefore, existing research has predominantly used the VRS model to derive university efficiency [10,13,25,38]. With respect to measurement orientation, we choose the output-oriented model rather than the input-oriented model. The output-oriented model fixes the input and explores the possibility of output expansion. The output orientation is more appropriate for university assessment than input orientation, because public sector organizations tend to maximize the outputs given the resource available. A lot of prior studies have used the output-oriented model to assess university performance [13,14,25]. In sum, in this study we employ the output-oriented VRS model.

We use the following notations to formulate the models. We let $j$ denote the index of the university for $j = 1, ..., n$; $k$ denotes the university under evaluation; $\lambda_i$ denotes the efficiency score for university $k$; $\lambda_i = (\lambda_{ij}, \lambda_{kj})$ is the vector of weights for the units; $x_i = (x_{i1}, x_{i2}, ..., x_{im})$ denotes the vector of $m$ inputs for university $j$; $g_i = (g_{i1}, g_{i2}, ..., g_{is})$ denotes the vector of $s$ outputs for university $j$. The model to evaluate the efficiency of the $k$-th DMU is specified as the following linear program.

$$\begin{align*}
\text{Max} \quad & \hat{\xi} \\
\text{s.t.} \quad & x_k - \sum_{j=1}^{n} \lambda_{ij} x_{ij} \geq 0, \quad i = 1, ..., m \\
& \hat{\xi} g_k + \sum_{j=1}^{n} \lambda_{ij} g_{ij} \geq 0, \quad h = 1, ..., s \\
& \sum_{j=1}^{n} \lambda_{ij} = 1 \\
& \lambda_j \geq 0, \quad \forall j = 1, ..., n; \quad \hat{\xi} \text{ unconstrained}
\end{align*}$$

(1)

The final efficiency score is the inverse of $\hat{\xi}$, i.e., $\varphi_i = 1/\hat{\xi}_i$. Note that if the constraint $\sum_{j=1}^{n} \lambda_j = 1$ in (1) is dropped, we obtain the CRS model and the CRS efficiency.

While a great many studies have championed the use of DEA for university assessment due to its capability of dealing with multiple inputs and outputs without assumptions on the functional form of the production process [13,26], the method itself cannot yield statistical inference and may suffer from bias caused by sampling variation. The efficiency scores from DEA are biased upward because the DMUs are benchmarked against the observed frontier but this observed frontier cannot be better than the true frontier. A remedy for the problem is the bootstrapping method for DEA developed by Simar and Wilson [46]. The bootstrapping DEA works by resampling the empirical data to obtain a series of pseudo datasets and computing the efficiency scores from these pseudo datasets. The method follows the steps below:

- Step 1: For all the DMUs, generate a pseudo dataset $[x_i, g_i]_{i=1, ..., n}$ by using the bivariate kernel density estimation and the reflection method proposed in Ref. [46].
- Step 2: Calculate the efficiency scores using the pseudo dataset obtained in Step 1.
- Step 3: Repeat Step 1 and Step 2 for a large number $B$ times ($B = 2000$ as suggested in Ref. [46]) to obtain a series of efficiency scores. Compute the bias-corrected efficiencies as in Ref. [46].

The computation is carried out with FEAR, a package for frontier efficiency analysis in R [47].

3.2. Resource allocation model

Because the Chinese government has strong controls over the resource allocation in higher education, it is appropriate to model the resource allocation problem from a central planner’s perspective. In this problem, the natural objective of the central planner is to allocate resources among the universities in order to maximize the total quantity of desirable outputs from all universities. Various DEA-based resource allocation models have been proposed [37–39]. We use a method in the spirit of [37]. Compared to other DEA-based models, the method of [37] assumes the DMUs are able to adjust their inputs and outputs in the short-term within an explicitly specified transformation possibility set based on the current values. Different from other resource allocation approaches, to control for the feasible range of adjustment, the method imposes a critical assumption that all DMUs’ efficiency scores cannot deteriorate after resource allocation. This assumption provides a guarantee on the worst performance for each single university after resource allocation. The central planner uses multiple-objective linear programming to find the optimal mix of inputs and outputs adjustment to maximize the overall outputs. The downside of the method is that it is more computationally demanding. Below we describe the method in details.

As in a typical resource allocation problem, we first introduce constraints on the ranges of allowable adjustment for the inputs and outputs of the DMUs. To model the adjustment of inputs, we assume that $x_{ij}$, the $i$-th input of the $j$-th DMU, can be adjusted to $x_{ij} + \Delta x_{ij}$ after resource allocation optimization. The constraints on the ranges of allowable change of inputs may arise due to fairness and feasibility concerns regarding resource allocation. For example, to maintain a certain degree of balance of resource allocated to different regions, the central planner may only adjust the input for individual universities in a certain range. For the $i$-th input of the $j$-th DMU, we assume the adjustment $\Delta x_{ij}$ must be bounded between $L_{ij}^0$ and $U_{ij}^0$, i.e.,

$$L_{ij}^0 \leq \Delta x_{ij} \leq U_{ij}^0, \quad \text{for } i = 1, ..., m; \quad j = 1, ..., n$$

(2)

where $L_{ij}^0$ and $U_{ij}^0$ are exogenously determined by the central planner. Moreover, for the total amount of the $i$-th input, $\sum_{j=1}^{n} \Delta x_{ij}$, it is assumed that the allowed range of change is $\Delta x_i$, i.e.,

$$\sum_{j=1}^{n} \Delta x_{ij} \leq \Delta x_i, \quad \text{for } i = 1, ..., m$$

(3)

A positive (negative) $\Delta x_i$ means the total resource use of the $i$-th
input is increased (decreased).

For the \( h \)-th output of the \( j \)-th DMU, we assume the adjustment \( \Delta g_{hj} \) must be bounded between \( L_{ij}^f \) and \( U_{ij}^f \), i.e.,
\[
L_{ij}^f \leq \Delta g_{hj} \leq U_{ij}^f, \quad \text{for } h = 1, \ldots, s; \ j = 1, \ldots, n
\]  
(4)

There is no constraint on the upper bound for total output \( \Delta g_{hi} \), because total output is the objective the central planner would like to maximize. But the change of total output must not fall below a predetermined level \( \Delta q_i \), i.e.,
\[
\sum_{j=1}^{n} \Delta g_{hj} \geq \Delta q_i, \quad \text{for } h = 1, \ldots, s
\]  
(5)

In fact, resource allocation can affect all types of outputs, and some outputs may be maximized at the expense of others. Therefore, we need (5) to specify the bottom-line output performance that the allocation should satisfy.

In addition to the range constraints on inputs and outputs in (2)–(5), it is natural to require that an individual DMU’s efficiency after resource allocation could not deteriorate compared to the efficiency before resource allocation, a central principle proposed in Ref. [37]. The goal of the central planner is to decide the optimal input and output mix of changes to maximize the amount of the weighted outputs. Incorporating the aforementioned considerations in resource allocation, the optimization program can be developed as follows.

\[
\text{Max } \sum_{h=1}^{s} w_h \Delta g_{hj} \\
\text{s. t. } (x_{ik} + \Delta x_{ik}) - \sum_{j=1}^{n} x_{ij} \lambda_{kj} \geq 0, \quad i = 1, \ldots, m; \ k = 1, \ldots, n
\]
\[- \varphi_k (g_{ih} + \Delta g_{ih}) + \sum_{j=1}^{n} g_{hj} \lambda_{kj} \geq 0, \quad h = 1, \ldots, s; \ k = 1, \ldots, n
\]
\[
\sum_{j=1}^{n} \Delta x_{ij} = 1, \quad k = 1, \ldots, n
\]  
(6)

In formulation (6), \( \varphi_k \) denotes the VRS efficiency score derived from (1) with the bootstrapping procedure. The model implies the efficiency score of the \( k \)-th DMU after resource allocation benchmarked against all other DMUs cannot be reduced to less than \( \varphi_k \), since the first three rows of constraints in (6) are the same as the VRS model of (1).

The decision variables in (6) include the change of inputs \( \Delta x_{ij} \), the change of outputs \( \Delta g_{hj} \), and the weights \( \lambda_{kj} \). In the objective function, \( \{w_h\} \) is a set of weights that reflect the central planner’s preference over the tradeoffs among the outputs in resource allocation. For instance, the central planner may favor patents over papers, so it should assign a larger weight to patents than papers. If the central planner is indifferent between the outputs, it should assign balanced weights to them. Finally, an examination of the objective and constraints indicates (6) is a linear program and can be solved efficiently.

4. Data and variables

The construction of input and output variables is a critical first step in DEA. The research performance of universities depends on a wide spectrum of factors. An all-inclusive model would simply be impossible. In this paper, we draw on literature as well as data availability to construct a group of inputs and outputs to capture the research performance as accurately and comprehensively as we can. Specifically, we use the following five variables to capture the inputs \( \{x_{ij}\} \) of universities in model (1):

- \( \text{R&D Staffs.} \) This is the number of R&D staffs in a university, measured in terms of full-time equivalence (FTE). The measure has been used extensively in studies on research performance [3,13].
- \( \text{Faculties.} \) This is the number of faculty members of a university, including lecturers, assistant professors, associate professors and full professors. It is also measured in FTE.
- \( \text{Postgraduates.} \) This is the number of postgraduates in a university, measured in FTE. In China, postgraduates generally participate in research projects and produce research outputs. Similar measures have been adopted in literature [18]. R&D Staffs, Faculties and Postgraduates together represent the physical labor input of universities in generating research outputs.
- \( \text{Government Funding.} \) This is the amount of research grant from the government, measured in 1000 RMB. It is the input that is controlled by the government. We will focus on the re-allocation of government funding in resource allocation analysis.
- \( \text{Industry Funding.} \) This is the amount of research grant from the industry, measured in 1000 RMB. It is not under the control of the government.

The output performance of research activities is multi-dimensional. We employ the following three variables for the outputs \( \{g_{ih}\} \) in model (1):

- \( \text{Papers.} \) This is the number of papers published in year, including papers on domestic and international journals. Publication of academic papers is the primary outcome of research activity. The measure is used in most of the university assessment papers [9].
- \( \text{Patents.} \) This is the number of patent applications submitted, including domestic and international patents. Patents filed have been widely used as a measure of research output [23].
- \( \text{Knowledge Transfer.} \) This is the revenue from knowledge transfer, measured in 1000 RMB. Knowledge transfer from universities to the private sector can take various forms, such as technology licensing, spinoff, and consultation. Recently, knowledge transfer is becoming an increasingly important measure of research outputs [25].

It is noteworthy that the above model does not include any outputs reflecting the teaching perspective of the universities. In practice, teaching is an important mission of the universities and is jointly produced along with research by the universities. Therefore, teaching should not be completely ignored in research resource allocation. However, we lack data on teaching measures such as number of degrees awarded and number of graduating students, since the government does not disclose such data. In addition, constructing proper teaching outputs is a hard task, as evidenced by Ref. [18] (pp. 687), an early study on Chinese universities, “there are no satisfactory measures of teaching outputs.” Consequently, several prior studies on research performance have ignored teaching [10,17,18]. We note that the exclusion of teaching output may bias the results, so the research allocation scheme generated without teaching should be interpreted with caution. It is also worth mentioning that R&D Staffs and Faculties are mutually exclusive in the higher education system of China. R&D staffs can supervise graduate students on research just as professors, but have limited teaching duties. Therefore, they should be treated as separate
inputs.

To construct the variables, we collect the data from the annual statistics bulletin compiled and published by Ministry of Education in China for the period 2014–2016. The bulletin is the most authoritative, comprehensive, and reliable source of data on China’s higher education. While the bulletin reports data on hundreds of universities, we focus on 64 universities that are directly affiliated with the Ministry of Education. These universities include almost all top universities in China and receive more than 80% of the total research funding for higher education institutions according to the bulletin reports. For each university, data for 2014–2016 are aggregated by averaging for the purpose in computation. The reason of using average value is to mitigate the bias caused by time lag between funding and research outputs as well as year-to-year fluctuations [3]. It is notable that to effectively distinguish between efficient and inefficient DMUs by DEA, the number of DMUs should be at least twice the product of number of inputs $m$ and number of outputs $s$ [48]. Our model satisfies this condition.

Table 1 shows the descriptive statistics of all variables used in this paper. We can observe the dispersion of government funding is big, with the maximum of 2.4 billion RMB being around 300 times the minimum of 8 million RMB. Meanwhile, the gap between the minimum and the maximum outputs is huge.

<table>
<thead>
<tr>
<th></th>
<th>R&amp;D Staffs</th>
<th>Faculties</th>
<th>Postgraduates</th>
<th>Government Funding</th>
<th>Industry Funding</th>
<th>Papers</th>
<th>Patents</th>
<th>Knowledge Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
<td>FTE</td>
<td>FTE</td>
<td>FTE</td>
<td>1000 RMB</td>
<td>1000 RMB</td>
<td>No.</td>
<td>No.</td>
<td>1000 RMB</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>870</td>
<td>1732</td>
<td>926</td>
<td>538614</td>
<td>391434</td>
<td>4095</td>
<td>764</td>
<td>35117</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>771</td>
<td>1103</td>
<td>842</td>
<td>511663</td>
<td>429055</td>
<td>2989</td>
<td>650</td>
<td>94910</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>20</td>
<td>73</td>
<td>21</td>
<td>8090</td>
<td>6287</td>
<td>43</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>4663</td>
<td>6515</td>
<td>5087</td>
<td>2406583</td>
<td>2392560</td>
<td>13319</td>
<td>2994</td>
<td>705329</td>
</tr>
<tr>
<td><strong>25th Quartile</strong></td>
<td>399</td>
<td>926</td>
<td>421</td>
<td>196118</td>
<td>108090</td>
<td>2023</td>
<td>273</td>
<td>1600</td>
</tr>
<tr>
<td><strong>75th Quartile</strong></td>
<td>1021</td>
<td>2203</td>
<td>1101</td>
<td>695978</td>
<td>497131</td>
<td>5167</td>
<td>1078</td>
<td>33303</td>
</tr>
</tbody>
</table>

Table 2 shows the bias-corrected efficiencies for all the universities, ranked from high to low. None of the universities is able attain perfect efficiency of unity. There are three universities that drop below 0.4 in efficiency. The inefficiency is very likely to be caused by the fields of research that these universities focus on. For instance, China University of Petroleum (Beijing) is a top university in the field of petroleum engineering. It receives a huge amount of research funding from dominant Chinese state-owned petroleum companies like China National Petroleum Corporation and China Petrochemical Corporation. The research funding from these state-owned companies is usually based on practical projects from these companies, and the uttermost objective is to generate economic benefits that the companies can garner. Therefore, for these projects, research output in the format of publication is not a top priority. Similarly, Beijing Jiaotong University has one of the best and biggest transportation research programs in China and receives a significant fraction of research funding from the state-owned China Railway Corporation. The nature of such research funding is similar to that of China University of Petroleum.

It is also intriguing to see that in general the normal universities in the list (i.e., universities that originally were established to train teachers) do not perform well. Northeast Normal University, Huazhong Normal University, East China Normal University, and Beijing Normal University are all ranked close to the bottom of the list. The best normal university, Shaanxi Normal University with an efficiency of 0.670, is ranked at the 41st position. The weak performance of normal universities is caused by their traditional positioning in the Chinese education system. All these normal universities were traditionally charged with the task of providing training for teachers [49], and consequently research was not a priority. During the reform of the Chinese education system, these top normal universities have been striving to shift the focus from teacher training toward research. The transition to a top research-oriented university is costly and takes time. The assessment results show that top normal universities still have some way to go before transitioning into excellent research-oriented universities.

We observe that on average the 985 universities do exhibit a slight edge over the non-985 universities in the list but the difference is far from significant. Overall, 31 of the 64 universities in the list are funded by the 985 Project. They achieve an average efficiency of 72.9%, which is only slightly better than the overall average of 69.7%. However, a t-test to compare 985 and non-985 universities fails to yield significant result. The result indicates that the 985 universities, despite of their strong financial support from the government, do not perform significantly better than the non-985 universities on average. Similar to Fig. 1, the efficiency results allude to potential inadequacy of funding allocation. Among the 985 universities, four universities fall into the bottom ten of the list. Lanzhou University, located in the northwestern province of Gansu, has been struggling under economic pressure and loss of talents to eastern provinces. Hunan University with an efficiency of 0.334 has the worst performance among the 985 universities. In the meanwhile, universities funded by the 985 program do tend to occupy higher positions given that four of the top five universities are 985 universities. The result is similar to [10] which finds that heavily

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3 The bulletins are publicly available at http://www.moe.gov.cn/s78/A16/A16_tdjc/.
funded elite universities take top positions in efficiency ranking.

### 5.2. Resource allocation

We solve the resource allocation problem in model (6) by adjusting the input variable, Government Funding, for each university. Financial allocation from the government is the primary source of research funding for Chinese universities. The government as a central planner has the obligation to put the research grant to the best use. A reasonable objective for the government is to allocate the grants to maximize the total outputs from all universities. In allocating the research grant, the government usually faces constraints on the range of resources that can be allocated to an individual university and the availability of total resources. The constraints on resource allocation to an individual university can arise due to fairness and regional balance considerations. The resource availability constraint limits the total quantity allocated to all universities and usually can be linked to the economic status of the country. We focus on the adjustment of Government Funding since this is the factor directly controlled by the government. The other input variables (i.e., R&D Staffs, Faculties, Postgraduates, Industry Funding) are to a large degree determined by the operations and managerial decisions of an individual university itself, and thus can be assumed to be fixed in the resource allocation problem from a central planner's perspective. Implementation details of model (6) follow.

---

Table 2

<table>
<thead>
<tr>
<th>University</th>
<th>Efficiency</th>
<th>University</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanjing Agricultural University</td>
<td>0.910</td>
<td>Tongji University*</td>
<td>0.744</td>
</tr>
<tr>
<td>Peking University*</td>
<td>0.873</td>
<td>Huazhong University of Science and Technology*</td>
<td>0.719</td>
</tr>
<tr>
<td>South China University of Technology*</td>
<td>0.866</td>
<td>China Agricultural University*</td>
<td>0.713</td>
</tr>
<tr>
<td>Tianjin University*</td>
<td>0.861</td>
<td>Beijing University of Science and Technology</td>
<td>0.711</td>
</tr>
<tr>
<td>Northwest A&amp;P University*</td>
<td>0.859</td>
<td>East China University of Science and Technology</td>
<td>0.710</td>
</tr>
<tr>
<td>Donghua University</td>
<td>0.855</td>
<td>China Pharmaceutical University</td>
<td>0.702</td>
</tr>
<tr>
<td>Sichuan University*</td>
<td>0.854</td>
<td>China University of Mining and Technology (Beijing)</td>
<td>0.687</td>
</tr>
<tr>
<td>China Ocean University</td>
<td>0.853</td>
<td>Northeastern University*</td>
<td>0.684</td>
</tr>
<tr>
<td>Fudan University*</td>
<td>0.842</td>
<td>Shaanxi Normal University</td>
<td>0.670</td>
</tr>
<tr>
<td>Central South University*</td>
<td>0.839</td>
<td>Sun Yat-sen University*</td>
<td>0.669</td>
</tr>
<tr>
<td>Hohai University</td>
<td>0.838</td>
<td>Northeast Forestry University</td>
<td>0.626</td>
</tr>
<tr>
<td>Shanghai Jiaotong University*</td>
<td>0.837</td>
<td>Southwest University</td>
<td>0.608</td>
</tr>
<tr>
<td>Zhejiang University*</td>
<td>0.835</td>
<td>Changan University</td>
<td>0.600</td>
</tr>
<tr>
<td>Wuhan University*</td>
<td>0.833</td>
<td>Huazhong Agricultural University</td>
<td>0.600</td>
</tr>
<tr>
<td>Communication University of China</td>
<td>0.830</td>
<td>Dalian University of Technology*</td>
<td>0.599</td>
</tr>
<tr>
<td>Renmin University*</td>
<td>0.825</td>
<td>Beijing University of Posts and Telecommunications</td>
<td>0.596</td>
</tr>
<tr>
<td>Beijing University of Chinese Medicine</td>
<td>0.819</td>
<td>North China Electric Power University</td>
<td>0.589</td>
</tr>
<tr>
<td>China University of Political Science and Law</td>
<td>0.818</td>
<td>Xian University of Electronic Science and Technology</td>
<td>0.576</td>
</tr>
<tr>
<td>Nanjing University*</td>
<td>0.818</td>
<td>Xiamen University*</td>
<td>0.558</td>
</tr>
<tr>
<td>Southwest Jiaotong University</td>
<td>0.817</td>
<td>University of Electronic Science and Technology*</td>
<td>0.554</td>
</tr>
<tr>
<td>Jiangnan University</td>
<td>0.816</td>
<td>China University of Geosciences (Beijing)</td>
<td>0.522</td>
</tr>
<tr>
<td>Tsinghua University*</td>
<td>0.810</td>
<td>Wuhan University of Technology</td>
<td>0.518</td>
</tr>
<tr>
<td>Hefei University of Technology</td>
<td>0.809</td>
<td>Northeast Normal University</td>
<td>0.514</td>
</tr>
<tr>
<td>Southeast University*</td>
<td>0.800</td>
<td>Beijing University of Chemical Technology</td>
<td>0.514</td>
</tr>
<tr>
<td>Xi'an Jiaotong University*</td>
<td>0.798</td>
<td>Lanzhou University*</td>
<td>0.494</td>
</tr>
<tr>
<td>Nankai University*</td>
<td>0.794</td>
<td>China University of Geosciences (Wuhan)</td>
<td>0.491</td>
</tr>
<tr>
<td>China University of Petroleum (East China)</td>
<td>0.779</td>
<td>Huazhong Normal University</td>
<td>0.481</td>
</tr>
<tr>
<td>Shandong University*</td>
<td>0.772</td>
<td>East China Normal University*</td>
<td>0.467</td>
</tr>
<tr>
<td>Jilin University*</td>
<td>0.771</td>
<td>Beijing Normal University*</td>
<td>0.429</td>
</tr>
<tr>
<td>Chongqing University*</td>
<td>0.763</td>
<td>China University of Petroleum (Beijing)</td>
<td>0.353</td>
</tr>
<tr>
<td>Beijing Forestry University</td>
<td>0.749</td>
<td>Hunan University</td>
<td>0.334</td>
</tr>
<tr>
<td>China University of Mining</td>
<td>0.745</td>
<td>Beijing Jiaotong University</td>
<td>0.290</td>
</tr>
</tbody>
</table>

The label "*" indicates the universities under the 985 funding program.
In this study, we assume that total amount of Government Funding can be changed at a rate proportional to the country’s GDP growth. In fact, Chinese government has a goal of appropriating 4% of GDP for education [8], and pegging the educational expenditure to GDP would imply educational expenditure changes at the same pace as GDP. Because China’s official GDP growth was 6.7% in 2016 and was expected to slow down further, we assume the total Government Funding can be increased by no more than 6.5% based on the 2014–2016 level, i.e.,

\[ \sum_{j=1}^{n} \Delta x_{ij} \leq \Delta r_e = 0.065 \times \sum_{j=1}^{n} x_{ij}, \]

(7)

where \( v \) corresponds the input of Government Funding. Further, we do not allow for deterioration of the total outputs so no output can be worse off after resource allocation, i.e.,

\[ \sum_{j=1}^{n} \Delta q_{hj} \geq \Delta q_h = 0, \quad \text{for } h = 1, \ldots, s. \]

(8)

To implement model (6), we consider two settings of adjustment range for \( \Delta x_{ij} \) and \( \Delta q_{hj} \), a conservative setting where a 10% adjustment range is allowed for Government Funding and outputs of an individual university, and a more aggressive setting where a 30% range is allowed. We consider several possible settings in the choice of weights assigned to the three outputs in the objective function of model (6). The weighting scheme reflects the preference of the central planner regarding different types of research outputs. We consider four weighting schemes with the first three schemes assigning all of the weight to a single output and the last scenario evenly distributing the weight to three outputs. Overall a total of eight scenarios are considered. We summarize all scenarios as combinations of weighting scheme and adjustment range in Table 3.

We summarize the adjustment of inputs, outputs, and change of efficiencies after resource allocation in Table 4 for all the scenarios. In scenarios A and E where the central planner prioritizes the output of research publication, the total papers grow by 7.37% and 18.05% respectively. Average efficiencies increase by 3.44% and 9.33%. The total patents and total knowledge transfer also increase by 5.8% and 4.2%, respectively. The changes of the input and the three outputs are more significant under scenario E where larger adjustment ranges are allowed according to Table 3. Similar patterns can be observed for the remaining six scenarios. Among scenarios (A, B, C, D) where a 10% adjustment is allowed for the input/outputs of an individual university, scenario B to prioritize patent application can achieve the best efficiency improvement of 9.47%. Among scenarios (E, F, G, H) where a 30% adjustment is allowed for the input/outputs of an individual university, scenario H can achieve the best efficiency improvement of 12.63%.

It is notable that in scenarios D and H where the three types of outputs are equally desirable for the central planner, resource allocation yields more balanced results with all three outputs improved simultaneously. Moreover, the lower bounds on outputs are not constraining in scenario D. Scenarios A has a slight edge over D in terms of publication (7.37% vs. 6.40%). But scenario D has better performance than A over patent and knowledge transfer. The comparison between C and D is similar. Despite scenario C prioritizes knowledge transfer, D has the same knowledge transfer performance as C and clearly beats C in publication and patent. Scenario B performs significantly better than D in patent (13.24% vs. 5.07%). The comparison between scenarios (E, F, G) and H exhibits similar patterns. Therefore, a balanced output weighting scheme can yield an almost as good outcome as when the central planner gives priority to publication and knowledge transfer. However, if patent is the most desirable output, balanced weighting is far from satisfactory.

Also, comparison between the conservative scenarios (A, B, C, D) and the aggressive scenarios (E, F, G, H) indicates that the aggressive scenarios consume more government funding than the conservative scenarios. But the increase in the desired output under aggressive scenarios in general may triumph over the increase of funding. For example, scenario E requires 36,583 millions RMB in government funding, about 1.8% higher than the amount of 35,953 millions RMB under scenario A. But the total paper output of scenario E is almost 10% higher than the amount of A. So allowing for aggressive adjustment can generate significantly more outputs.

Table 5 provides details on the distribution of government funding change for all the scenarios. Under scenarios (A, B, C, D) none of the universities should receive 10% more government funding compared to the current funding level, as specified by the range constraint. If patent is the priority, then the central planner should reduce the funding for four universities. In other three scenarios there is no need to reduce government funding. But under the more flexible scenarios (E, F, G, H), cutting of government funding is more common.

For illustration, Fig. 2 shows the change of government funding for individual universities under scenario A when publication is the top priority. Three universities should be granted the maximum increase in government funding, as labeled on the graph. Among them, Sichuan University and Central South University belong to the top 5 program, while Hefei University of Technology does not. It is notable that none of these three universities breaks into the top 5 in the ranking of research efficiencies in Table 2. Total government funding allocated to all the universities should increase by 3.9%. It is also noteworthy that five universities have received more than 1500 million RMB in government funding but the funding change for them should be kept below 6%.

6. Discussion and conclusions

Resource allocation in higher education is of critical importance for policymakers, university administrators, researchers, and the general public. This paper studies the resource allocation problem for a central planner by basing the resource allocation decision on performance. Specifically, each university’s research performance is derived from DEA efficiency analysis [50,51], employing quantities of publications, patents and knowledge transfer as outputs, and sizes of faculties, R&D staffs, postgraduates, government funding and industry funding as inputs. Next, as the approach developed in Ref. [37], the central planner maximizes the total research outputs across all universities through allocation of resource, subject to the constraint that each individual university’s efficiency cannot deteriorate under the new allocation scheme. This paper demonstrates the applicability of the DEA-based resource allocation approach in the higher education sector by applying it to allocate government research funding among major Chinese universities. The results show that Chinese universities have very diverse research performances and allocation of government funding can be
to employ certain performance indicators and develop allocation funding allocation. The paper also complements the existing research [26-29], no prior study has linked the assessment results to research outputs at the will of the central planner. Second, resource allocation based on efficiency does not deteriorate after resource allocation. Third, the objective to maximize the outputs is explicitly modeled in an optimization problem and weights can be assigned to different types of research outputs at the will of the central planner. Policy-wise, the higher education section in China is transitioning to a new funding system, i.e., the double first-class plan. The plan has been officially unveiled in September 2017. Performance-based funding is a central pillar of the plan. This study provides evidence that supports the implementation of the double first-class plan. The empirical results indicate the existence of disparity and efficiency in the current funding system. In the first place, on average the difference between the 985 and the non-985 universities in research efficiency is not significant, even though the 985 universities are more heavily funded by the government. This suggests that there may be space for the government to allocate the research fund to better usage. Moreover, some underperforming universities with low research efficiencies have been included in prominent funding programs (e.g., the 985 Project), while quite some universities with high research efficiencies have been excluded. The observation is in line with prior studies [9,10]. The unsatisfactory research performance of some of the elite universities included in prominent funding programs may be attributable to local economy conditions. Despite the advantageous status of being admitted into prominent funding programs, a set of universities such as Hunan University and Lanzhou University are hugely disadvantaged in attracting top scholars and students compared to universities in coastal provinces, due to the economic state. The resource allocation results help us identify the universities that should receive more funding. Policymakers should pay more attention to these universities in the future funding programs. Specifically, policymakers may consider to enlarge the scope of the funding programs to include more universities currently not in the programs.

Moreover, the results show that in resource allocation, a balanced formulas to distribute the funds [52]. For example, the UK’s PBF program represents a university’s overall research performance by a weighted average of three important features of research (i.e., outputs, impact and environment). Each feature is assessed and quantified by panels of experts based on predetermined criteria [6]. In the “Norwegian Model”, administrators derive field-specific publication points for each university based on bibliographical records, and the ensuing fund allocation is based on the fraction of the university’s publication points out of total points [7]. The proposed approach differs from the aforementioned methods in three critical ways. First, unlike the commonly used weighted average measure, DEA efficiency scores are derived to capture the research performance. DEA provides a holistic measure of the efficiency in transforming multiple inputs into multiple outputs. Second, resource allocation based on efficiency analysis takes production possibility set into account, such that it can be guaranteed that a university’s efficiency does not deteriorate after resource allocation. Third, the objective to maximize the outputs is explicitly modeled in an optimization problem and weights can be assigned to different types of research outputs at the will of the central planner.

The unit of funding is 1million RMB.

### Table 4
Overall performance after resource allocation.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Original</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Efficiency</td>
<td>0.697</td>
<td>0.721</td>
<td>3.44%</td>
<td>0.763</td>
<td>9.47%</td>
</tr>
<tr>
<td>Total Government Funding</td>
<td>34471</td>
<td>35953</td>
<td>4.30%</td>
<td>36214</td>
<td>5.06%</td>
</tr>
<tr>
<td>Total Papers</td>
<td>262073</td>
<td>281399</td>
<td>7.37%</td>
<td>276114</td>
<td>5.36%</td>
</tr>
<tr>
<td>Total Patents</td>
<td>48879</td>
<td>48893</td>
<td>0.03%</td>
<td>55350</td>
<td>13.24%</td>
</tr>
<tr>
<td>Total Knowledge Transfer</td>
<td>2248</td>
<td>2248</td>
<td>0.00%</td>
<td>2249</td>
<td>0.04%</td>
</tr>
</tbody>
</table>

The unit of funding is 1million RMB.

### Table 5
Distribution of government funding change after resource allocation.

<table>
<thead>
<tr>
<th>Change of government funding</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>8</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>(0, 3%)</td>
<td>25</td>
<td>10</td>
<td>25</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>(3%, 5%)</td>
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Fig. 2. Government funding change for universities under scenario A.

The paper complements the existing research of performance assessment by DEA in higher education sector. In fact, while DEA is a popular approach for benchmarking the university performance [26-29], no prior study has linked the assessment results to research funding allocation. The paper also complements the existing research on PBF for higher education institutions. All existing PBF models have to employ certain performance indicators and develop allocation optimized to enhance the aggregate research outputs from all universities.
objective that considers different output measures simultaneously can yield good results. The central planner should be cautious of placing too much emphasis on a single research output. Overemphasis on paper or patent output in research funding allocation has a detrimental effect on overall research performance. Therefore, policymakers should take a balanced perspective in evaluating research outputs across multiple dimensions. Indeed, as the Chinese economy is increasingly driven by innovations, policymakers in China have started to place greater emphasis on knowledge transfer, which has long been neglected in the research funding system of the country. Several policies have been introduced to galvanize and facilitate the commercialization of academic research. Finally, it is in general beneficiary to allow more aggressive adjustment of individual university’s funding. This suggests that a radical reform of the funding may be desirable.

This study suggests several directions for future research. First, we have assumed the inputs (e.g., industry funding, faculties, R&D staffs, postgraduates) not under the control of the central planner are fixed. But in reality, universities can adjust their faculties and staffs, and the quantity of industry funding may fluctuate over time. From the central planner's perspective, the inputs are uncertain. Hence the impact of resource allocation is also uncertain and may differ from the central planner’s expectation. Therefore, uncertainty poses a grave challenge to the central planner. How to introduce uncertainty into the current framework is a critical research problem. Addressing uncertainty may require robustness measures of allocation. Second, due to data limitation, the current performance evaluation does not take the quality dimension fully into account. The output of knowledge transfer can deviate from the planner’s expectation. Therefore, uncertainty poses a grave challenge to the central planner.

Third, subject-mix of the universities should be taken into account. Complementing the current analysis with quality measures can incorporate critical aspects such as citations and number of highly cited papers. Therefore, policymakers should take a more holistic view of the overall research performance. Several policies have been introduced to galvanize and facilitate the commercialization of academic research. Expanding the higher education system in China, the research framework is generated to partially reorient fully into account. The output of knowledge transfer can deviate from the planner’s expectation. Therefore, uncertainty poses a grave challenge to the central planner.

References


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<td>Modelling energy demand from higher education institutions: A case study of the UK (2019)</td>
<td>Applied Energy (article from Elsevier)</td>
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Modelling energy demand from higher education institutions: A case study of the UK

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HIGHLIGHTS

\begin{itemize}
\item Energy consumption in higher education institutions (HEIs) modelled.
\item For the first time, panel data used, with cross-sectional and time-series variations.
\item Over time and across HEIs, energy use increases as income and size increase.
\item Economies of scale as HEIs grow, but energy use still rising with sector growth.
\item Research universities more energy intensive.
\end{itemize}

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Higher education
Building energy
Carbon emissions

ABSTRACT

Among the various sustainability goals of higher education institutions (HEIs), reducing energy use and carbon emissions are particularly important. However, not much is known about energy demand from the higher education sector – especially since there is a lack of robust models of energy demand in this sector. This paper, the first to utilize a panel dataset and advanced panel econometric techniques in order to model energy use in higher education, investigates variations in energy use between HEIs (cross-sectional analysis), and also changes in energy use over time (temporal analysis), using the UK as a case study. We argue that panel dataset and methods are more useful for understanding growth (and reduction) in energy use within the HE sector than the methods used within previous cross-sectional studies. Results show that, over time and also across the sector, energy consumption in the HEIs increases with increases in income and floor space, but at a slower rate. As HEIs grow overall (in terms of income, floor space, student and staff number) over time, they become more ‘energy efficient’ (using less energy per unit of area, population or income), indicating economies of scale in the temporal dimension. Results also show that after controlling for income and size, research intensive HEIs consume more energy. We also find a small but statistically significant effect of energy prices on energy consumption, as might be expected. Simulation using the model parameters for an example scenario suggests that energy consumption will continue to increase unless there is a significant change in the policies driving income growth and spatial expansion in the HE sector in the UK.

1. Introduction

Higher education institutions (HEIs) are not only places for knowledge creation and dissemination, but are also major employers, economic actors, and providers of cultural, recreational and infrastructure resources \cite{1}. The higher education (HE) sector often presents itself as leading on sustainability challenges – be it through research and technology development, dissemination of knowledge, good citizenship and environmental awareness of communities, students and staff or through changing its own corporate behaviour toward more sustainable practices \cite{2}. Reducing carbon emissions is the latest addition to the sustainability goals of the HE sector.

While past efforts to reduce energy use and carbon emissions from HEIs have generally focused on the energy performance of buildings, little is known about the underlying reasons for changes in energy demand, such as economic activity or population changes within the HE sector. This knowledge gap presents a substantial challenge in reducing energy use and carbon emissions, as gains from technical improvements...
to buildings and equipment can be negated by increases in energy demand that result from changes in “non-energy” policies and practices. For example, Royston [3] argues that non-energy strategies such as provision of luxurious student facilities, growth in numbers of students and staff, or increased research activity can lead to increases in demand that outweigh gains made through technical measures such as insulation or LED lighting. However, the impacts of these policies are rarely recognised, and are largely “invisible”. Therefore it is important to understand the drivers of energy use in the HE sector, especially through quantitative modelling, which is an under-researched area.

This paper addresses this gap in the international energy demand literature by developing an advanced econometric model to understand the effects of different factors on energy demand within HEIs.

The paper makes several methodological and empirical contributions to our current understanding of energy consumption from HEIs. Firstly, this is the first study to utilize temporal variations of energy use in a cross-section of HEIs, unlike previous studies ([4–6] in the USA and Taiwan), which use only cross-sectional data at one time point and have several important limitations (explained later) that make them less useful. Secondly, we apply advanced hybrid panel models [7], in addition to the more traditional panel data methods in modelling energy use from HEIs. Thirdly, our energy consumption model is also more comprehensive than previous ones with the inclusion of several new explanatory factors, including energy price, which is – somewhat surprisingly – missing from previous models. Finally, inclusion of temporal observations in the panel econometric models also allows forecasting of energy use in the future, which is important for energy and carbon planning and management purposes but is not possible from any of the previous cross-sectional models. Our energy modelling techniques and results thus have wider applications in the international HE sector.

The paper is laid out as follows: Section 2 briefly introduces the UK HE sector as a case study, including its energy reduction and carbon mitigation initiatives. Section 3 describes the existing international literature on energy use in the HE sector, identifying the key gaps and describing further the contributions of this paper. Section 4 describes the data and methods used in detail, Section 5 presents and discusses the modelling results, including simulation results for a future scenario. Section 6 draws conclusions and the broader implications of our results and models.

2. UK HE sector

2.1. State of the sector

As mentioned above, we use the UK as the case study country for modelling energy use from the HE sector. There were 162 publicly funded higher education providers in the UK during 2016/17, with 2.32 million students and around 420,000 staff [8]. Universities UK (a lobby group representing most UK universities) estimates that in 2014–15, UK universities generated £95 billion in gross output for the economy and contributed £21.5 billion to GDP, representing 1.2% of the UK’s GDP [8]. If all the HEIs in the UK were concentrated in one city, that would be the fifth largest city-economy in the UK [9]. Official data published by the Higher Education Statistics Agency (HESA) shows that HEIs own approximately 28.8 million m² of gross internal space [10]. Higher education has also been a fast-growing export sector [11], and UK universities have substantially increased their international student intake in recent years: the proportion of international students studying at UK universities increased from 14% in 2006–07 to 19% in 2015–16 [12]. Universities are often likened to towns or cities rather than places of work or study, because of their large size, population and various complex activities taking place on campus, including residential facilities for students, teaching and research. These diverse activities all have implications for energy demand.

2.2. Energy reduction and carbon mitigation initiatives

Overall the education sector (including primary and secondary education) is responsible for 13% of energy use in the UK [13]. In keeping with UK’s national carbon emission reduction target of 34% by 2020 from a 1990 baseline, in 2010 the regulator for English HEIs, Higher Education Funding Council for England (HEFCE), set a target of 43% reduction in carbon emissions (Scope 1 and 2) from the English HEIs between 2005 and 2020 [14]. However, not every HEI has the same target, rather individual institutions were allowed to set their own targets. The collective impact of institutional targets is 38%, which is lower than the sectoral target [15]. In order to incentivise HEIs to reduce their emissions, the capital investment framework of HEFCE was also modified [14]; however, this later became largely irrelevant due to changes in the structure of HE funding in England. Meanwhile, all Scottish Universities as of 2016 signed the Universities and Colleges Climate Commitment for Scotland (a public declaration that the institution acknowledges the Scottish Government targets to reduce carbon emissions by 80% by 2050). Universities in Scotland must also report carbon emissions to the Scottish Government [16]. In Wales, the sector regulator Higher Education Funding Council for Wales requires universities to have a carbon management strategy and target (which is set by the university).

To date, there has been some limited progress in reducing emissions. The English HE sector’s emissions peaked in 2009/10 at just over 2.1 million tonnes (CO₂ equivalent), and have since been on a downward trajectory (albeit with a slight rise in 2013/14). Sector emissions are now 1.7 million tonnes, which is 17% lower than the 2005 baseline used for HEFCE targets [17].

59% of English HEIs are currently behind schedule and will likely miss their targets [17]. 14 HEIs (11%) indeed increased their emissions between 2005/06 and 2015/16. Among the Russell Group of 20 research intensive HEIs, which are collectively responsible for half of all HEI emissions, emissions have only fallen by 11% from 2005 to 2015/16. If the current trend continues, the overall reduction from 2005 could be only 23% by 2020 [17]. Emissions from Scottish HEIs also increased by 6% between 2008/09 and 2014/15 [18]. While some improvement in carbon intensity of energy use has been achieved over time (through grid decarbonisation, use of renewables, installation of combined heat and power plants), increases in energy use – generally driven by growth –make it much harder to achieve absolute reductions in carbon emissions. As such, modelling energy demand from the HEIs is an important area of research not only from the cost and resource perspective, but also from the carbon management perspective.

3. Literature on modelling energy demand in HEIs

Although sustainability in the HE sector has attracted some academic interest, there are few studies investigating overall energy use. A large part of this literature focus on carbon emissions (or energy use) from individual institutions, specific buildings or specific interventions in an academic institution (e.g. [19–23]), which is outside our interest in whole sectoral studies. Studies investigating a group of schools (not HEIs) are not uncommon either (see e.g. [24–27]). Nearly all of these studies use energy audit or measurement data of a group of school buildings and use elementary descriptive statistics to explain consumption based on different characteristics. Pereira et al. [28] provide a useful survey of the studies on energy consumption in schools. Although simple correlation analysis has been employed in some studies

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1. Scope defines the different categories of emissions: scope 1 refers to ‘direct’ emissions from sources owned by the HEI (e.g. fuel use in a boiler); scope 2 refers to ‘upstream’ emissions generated by purchased electricity by the HEI; scope 3 refers to emissions resulting from activities of the HEI, but from sources not owned or controlled by the HEI (e.g. business travel by the academics).
to assess the strength of the relationship between various factors affecting energy use in schools, none of this literature attempts to use regression (econometric) methods to quantify the relationship.

In the UK, energy use in and carbon emissions from HEIs has received some attention, especially in the run-up to the Climate Change Act of 2008 and thereafter. Of these Fawcett [29] summarises estimates for emissions, including indirect emissions for business travel by students and staff. Ward et al. [11] use HEFCE data to review energy consumption, using primarily descriptive statistics of various energy indicators over various HEI groups. Distribution of fuel source has also been an area of investigation. Ward et al. [11] test pairwise correlation to understand the explanatory factors for energy consumption in HEIs, which is similar to Sinha et al.'s [30] research into GHG emissions in US universities. Robinson et al. [31] track GHG emissions from the Russell Group of research-intensive universities in the UK, and discuss their achievements against their own carbon targets. Altan [32] qualitatively investigates energy efficiency interventions in HEIs in the UK. Mazhar et al. [33] conduct semi-structured interviews of energy/environment-related managers to qualitatively discuss current management practices toward emissions reduction from the HEI sector. Royston [3] also conducts interviews with energy managers to understand current energy and carbon management practices in HEIs in the UK. Once again, quantitative modelling is missing from this body of work.

Only three studies – Fetcher [4], Klein-Banai and Theis [5] and Wang [6] – utilize econometric/regression modelling techniques to investigate energy use or carbon emissions from HEIs. The first two investigate greenhouse gas emissions and focus on US universities, while Wang [6] focuses on energy consumption from Taiwanese HEIs. Both the US studies use the same GHG inventory database – the American College & University Presidents’ Climate Commitment (ACUPCC) reporting system – but from different years. Fetcher [4] uses HEI size and weather (mean temperature in summer and/or winter) to explain carbon emissions (Scope 1 and 2) from 238 US HEIs. He uses gross area and full time equivalent student population to represent size in different model specifications, but never uses both in the same model to avoid multicollinearity. His major finding is that larger HEIs are less carbon-efficient per unit area, especially if the HEI offers a Doctoral degree.

Klein-Banai and Theis [5] improve upon Fetcher’s [4] model by dividing gross floor area into different use types (residential, laboratory, health care, etc.) and postulating that different types of use of building space have different carbon implications. They also replace mean temperature with heating degree days (HDD) and cooling degree days (CDD) to represent weather. Using regression models over a sample of 135 HEIs, Klein-Banai and Theis [5] also support Fetcher’s [4] finding that as building space increases, Scope 1 and 2 emissions increase at a faster rate. This study also includes regressions for combined Scope 1, 2 and 3 emissions, for both number of occupants and floor space. Fetcher [4] also found that HEIs with medical schools emit more compared to those without, which was also observed by Larsen et al. [19].

Wang [6] also uses cross-sectional data to model energy consumption in 51 Taiwanese universities. He uses three different independent metrics to represent energy use: energy consumption, energy use per unit area per year and energy use per student. The energy consumption model used floor area, land area and building density as explanatory factors. As in the previous studies, floor area is strongly and positively related managers to qualitatively discuss current management practices toward emissions reduction from the HEI sector. Royston [3] also reported and different breakdowns of both energy and carbon emissions were reported. For example, carbon emissions were separated by Scope 1, Scope 2 and Scope 3, as per the World Resource Institute’s [39] emissions reporting protocol. In this research we include only energy uses from Scope 1 and Scope 2 categories, emissions from which are under the HEFCE emissions reduction target, and which are less uncertain than Scope 3 emissions.

The number of universities reporting energy consumption in the

4. Data, model and methods

4.1. Data source

The UK Higher Education Statistics Agency (HESA) collects various self-reported statistics from the HEIs in the UK. Although the primary motivation is to collect information on university finance, students and staff, energy consumption data have also been collected since 2001/02 as part of the Estates Management System dataset. The early years (between 2001/02 to 2007/08) of the energy dataset are limited to some extent: e.g. universities in Scotland, Wales or Northern Ireland are not covered and energy use from different fuel types is not available either. However, energy consumption data for non-residential (university business) and residential (student accommodation) use are separated. Fig. 1 presents the distribution of total energy consumption in the HEIs in 2014/15, which shows a large variation in energy consumption among the HEIs.

With a view to monitoring carbon emissions from HEIs, HESA’s estates data collection was extended substantially from 2008/09: universities from all four UK nations were included, carbon emissions were also reported and different breakdowns of both energy and carbon emissions were reported. For example, carbon emissions were separated by Scope 1, Scope 2 and Scope 3, as per the World Resource Institute’s [39] emissions reporting protocol. In this research we include only energy uses from Scope 1 and Scope 2 categories, emissions from which are under the HEFCE emissions reduction target, and which are less uncertain than Scope 3 emissions.

The number of universities reporting energy consumption in the

**Fig. 1.** Distribution of energy use among the HEIs in year 2014, in ascending order of energy use.
Note that energy prices paid by the HEIs can often be negotiated with the

differences, which is generally done via the heating degree days (HDD) method. A heating degree day is a measure of how much (in degrees), and for how long (in days), the outside air temperature is below a certain level (www.degreedays.net) so that the building needs space heating. The assumption is that the greater the HDDs, the more artificial space heating will be used, and there is strong evidence that a building’s energy consumption is directly linked to HDDs (or cooling degree days in warmer climate, see e.g. [5]). Spatially and temporally disaggregated monthly HDD data is collected from degreedays.net (2016) for eighteen regions within the UK. HDDs are then assigned to each HEI depending on its location and annual observation period, which is then used to normalize respective energy consumptions against weather effects, by dividing energy consumption by respective HDDs and multiplying by the sample average HDD. Fig. 2 presents the evolution of this normalized, weather-corrected energy use with respect to income for all the HEIs in the dataset. Each line represents an HEI, showing the trajectory of its energy use with respect to income over the period. Different colour codes are used for those which are research intensive and those which are not. We define research intensive universities as those with at least 13% of their income from research contracts and grants, based on recent HESA finance statistics.

HEIs consume natural gas directly for space heating, while many HEIs own and operate Combined Heat and Power plants, which also use gas as feedstock; and nearly 30% of UK grid electricity is produced from natural gas, which is the largest share among all feedstocks [40]. As such natural gas prices are used to proxy for energy prices. Real gas price indices for the industrial sector are collected from the Department for Business, Energy and Industrial Strategy [41]. Nominal income is converted to real income using the Consumer Price Index (CPI) data from the Office for National Statistics [40]. Data on other characteristics of the HEIs, such as their membership of mission groups such as the Russell Group or the now-disbanded 1994 Group, are collected from relevant mission group websites. The arts/humanities/social science or science focus of a university is determined using the unit of assessments data of HEI submissions for the Research Assessment Framework (REF) in the UK.

4.2. Explanatory factors

Energy consumption in buildings is clearly a function of building characteristics — especially the size of the building, materials used, façade types, insulation and the quality of construction [42]. HEI’s energy use and gross internal area (GIA) — representing size — have the highest correlation. However, energy use patterns may vary substantially between different types of building use purposes, e.g. student dormitories, classrooms, laboratories, administrative offices, libraries, sports halls, etc. As such, it would have been preferable to have disaggregated GIA data, by these different uses. Unfortunately, such elaborate differentiation is not available in the HESA dataset. However, GIA is differentiated by residential and non-residential purposes. Therefore we include both residential and non-residential GIA as explanatory factors, instead of a single measure for total gross area. In the UK, the technical energy efficiency of buildings (energy use per unit floor space) is expressed through energy labels such as the Energy Performance Certificates for residential buildings or Display Energy Certificates for public or commercial buildings. While the most recent HESA dataset has some information on energy performance certificates, the data is incomplete (e.g. the total area under each energy efficiency groups do not equate to the total area of the HEI, and also not available for all years). Therefore it is not possible to include a building energy performance variable in our model. Age could have been a proxy, but different buildings in the same university are built in different eras, and also older buildings may or may not be refurbished to new standards, possibly making the correlation of age with energy use unclear.

Other explanatory factors included in the model are income and population (staff and student number, full time equivalent). The three variables of income, population and GIA are highly correlated and together represent the growth or contraction of HEIs. We also include income squared to account for the possibility of non-linear responses in energy consumption to increases in income. All of these variables vary with time within one HEI, and obviously between HEIs. We also control for other time dependent external factors that could affect sectoral energy use through explicitly including time in the specification. The price of energy is included to account for the potential negative effect of

...
energy price on energy demand.\textsuperscript{7}

In addition, we have information on the characteristics of HEIs which are time invariant, i.e. they are fixed over time for each HEI. It is quite possible that research focused, especially science and medical research focused HEIs, would consume more energy compared to a similar sized non-research intensive university and inclusion of such characteristics in the model improves the explanatory power further. Because of multicollinearity, however, we cannot include all of these variables at the same time (e.g. all Russell Group universities are research intensive). As such we test several combinations in our regression model. Energy use in HEIs thus has the following specification:

\[ E = f (GIA_{NR}, GIA_R, INC, INCSQ, OCC, HDD, PRC, T) \]  

(1)

where \( GIA_{NR} = \) Gross internal area – non-residential

\( GIA_R = \) Gross internal area – residential

\( INC = \) Income

\( INCSQ = \) Income squared

\( OCC = \) Number of occupants (staff + students, full time equivalent)

\( HDD = \) Heating degree days (or, energy corrected for HDD)

\( PRC = \) Price of natural gas

\( T = \) Time (continuous or dummy)

All the continuous variables are converted to logarithms. This has two advantages: firstly, it reduces the potential heteroscedasticity problem (i.e. variance increases with larger values) and secondly, the parameter estimates directly represent the elasticities of energy use with respect to the explanatory factors. Table 1 presents the summary statistics for the key variables in the model.

4.3. Panel econometric method

Our dataset is known as panel data in the literature, whereby the variables are observed for cross-sectional units – the HEIs – over several time periods. While it is possible to pool all the data together and estimate the model parameters through Ordinary Least Squares (OLS) regression technique, such a ‘pooled’ OLS approach assumes that each observation is independent from each other, which is clearly not the case in a panel dataset. As such a simple OLS method can result in erroneous estimation of the parameters.

On the other hand, panel econometric techniques recognize the special structure of the data and can lead to more efficient estimation of the parameters. Especially, it is never possible to include all the explanatory variables in a typical regression model, and the absence of some variables could lead to an omitted variable bias. Panel regression can control for these unobservable factors and also recognizes that the HEIs are heterogeneous units that can differ from each other\textsuperscript{[43,44]}. This is certainly a more plausible representation of reality than assuming all observations are similar, which is the implicit assumption of the pooled model.

The basic framework in a hypothetical one-way panel data model with one time varying and one time-invariant explanatory factor is:

\[ y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 z_i + \alpha_i + \epsilon_{it} \]  

(2)

where \( y_{it} = \) dependent variable

\( x_{it} = \) time variant explanatory factor

\( z_i = \) time invariant explanatory factor

\( \alpha_i = \) intercept for cross sectional units

\( i = \) subscript for cross-sectional unit

\( t = \) subscript for time unit

There are several ways a panel regression model can be estimated. A ‘between-effect’ (BE) model is defined as one using the within group (within each cross-sectional unit) mean of the variables:

\[ \bar{y}_i = \beta_0 + \beta_1 \bar{x}_i + \alpha_i + \bar{\epsilon}_i \]  

(3)

The BE parameters can explain the differences between the cross-sectional units, but lose the potentially rich information in the time dimension by reducing them to averages only. The parameter estimates can also be biased\textsuperscript{[45]}. Still, the model can be useful in explaining whether there are any systematic differences in energy consumption between, say, research-intensive and teaching-intensive HEIs or high income and low income HEIs. The cross-sectional models used in\textsuperscript{[4-6]} are all – in essence – BE models.

A fixed-effects (FE) model produces ‘within-effect’ estimates for parameters and is estimated by deducting Eq. (3) from Eq. (2) and running OLS on the transformed dataset:

\[ (y_{it} - \bar{y}_i) = \beta_1 (x_{it} - \bar{x}_i) + (z_i - \bar{\alpha}_i) \]  

(4)

In practice, the FE or within-effect parameters represent how the dependent variable in the cross-sectional units – on average – responds to changes in the independent variables in the temporal dimension. This is also equivalent to estimating Eq. (2) by introducing dummy variables for each cross-sectional unit, and as such assuming that the \( \alpha_i \)s represent the effects of all unobservable characteristics of the cross-sectional units. The biggest advantage of the FE model is that it allows the fixed effects (\( \alpha_i \)) to be correlated with the explanatory factors, which is often the case in practice and results in an unbiased estimate. The primary disadvantage is that the effects of time-invariant characteristics (e.g. research intensive vs. teaching intensive HEIs) cannot be determined as they are subsumed within the \( \alpha_i \)s. However, this is still the more popular method, given the researchers’ interest is often in the effects of a ‘change’ which is time-dependent and the appropriate interpretation of the parameter estimates in this context. Since our primary interest lies in the effects of change in the explanatory factors, this is also the primary model we are interested in.

A random effect (RE) model, on the other hand, assumes that the \( \alpha_i \)s are uncorrelated with the explanatory factors and randomly distributed (with zero mean and constant variance). In essence, RE parameter estimates are weighted averages of between-effect and within-effect estimators and Generalized Least Squares (GLS) or Maximum Likelihood (ML) methods are employed for estimation. If the assumptions hold, RE model estimates are more efficient than FE ones. RE formulation also allows modelling the effects of time-invariant characteristics, but any misspecification has a more serious consequence compared to FE models\textsuperscript{[44]}.

There is a large literature on the choice between FE and RE models. FE models are often described as the standard default in panel data modelling, especially in the field of economics\textsuperscript{[46]}. Subjectively, FE

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<td></td>
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<tr>
<td>Number of ex-G94 universities</td>
<td>15</td>
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<tr>
<td>Number of research intensive HEIs</td>
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</tbody>
</table>

\textsuperscript{7}Another variable that could affect consumption is the length of academic year which may vary between 9 and 12 months. Unfortunately we do not have any data on that. Also, the effect will likely be minimal, since our main interest is in the temporal dimension and HEIs do not significantly alter their academic term durations between different years.
models are used when the inference is conditional on the sample, while RE are used when inference about population from a sample of observations is required [47]. Interpretability of the parameters and robustness against misspecification (due to omitted variables, which is quite common) generally tilt the balance toward FE. Objective measures such as the Hausman test [48] are often used to guide the choice between FE or RE models.

4.4. Hybrid panel method

Mundlak [49] adds to the discussion by arguing that the choice is not between FE and RE models, but rather on how far the assumption of zero correlation between $\alpha_i$s and the explanatory factors can be relaxed and modelled within the RE framework. Mundlak [49] proposed a correlated random effect model, where he assumes that $\alpha_i = x_i \gamma + \nu_i$ and Eq. (2) becomes:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 \tilde{z}_i + x_i \gamma + \nu_i + \epsilon_{it}$$

(5)

In this formulation, the group mean $\tilde{z}_i$ picks up the correlation between the variable and $\alpha_i$, and $\nu_i$ becomes the error uncorrelated with the $x_i$s. The parameter estimate for $x_{it}$ is the same as the within or FE estimator. Similar to Mundlak's [49] approach is the 'hybrid' model [7], which decomposes $x_{it}$ into a between ($\tilde{z}_i$) and a within effect ($x_{it} - \tilde{z}_i$) in Eq. (2), again within the RE framework. The hybrid model thus takes the form:

$$y_{it} = \beta_0 + \beta_1 (x_{it} - \tilde{z}_i) + \beta_2 \tilde{z}_i + \beta_3 \tilde{z}_i + \mu_i + \epsilon_{it}$$

(6)

As in a typical RE model, $\mu_i$ is randomly distributed and uncorrelated with the explanatory factors, any correlation being picked up by the inclusion of $\tilde{z}_i$ in the model. In this formulation $\beta_2$ produces the same FE or within-effect as Eq. (5), while $\beta_3$ is the between-effect. The hybrid formulation allows us to test whether the within and between effects are the same, i.e. whether the effect of changes in one variable within a cross-sectional unit is the same as the effect of that variable on different cross-sectional units. More importantly it allows estimating the correct FE or within-effect parameter – which is the main interest – but also allows deciphering the effects of non-time varying characteristics ($z_i$) of the HEIs, although that can be measured with some bias. Hybrid models are becoming popular because of their flexibility and this will be the second model structure that we estimate. Bell and Jones [46] suggest that hybrid models should be preferred to FE models.

4.5. Econometric model specification

The final econometric specification of the model for HDD-corrected energy consumption from the HEIs is:

$$\ln E_{it} = \beta_0 + \beta_{\text{GLAN}} \ln GIA_{NR} + \beta_{\text{GBAU}} \ln GIA_{R} + \beta_{\text{INCSQ}} \ln INCSQ_i + \beta_{\text{MEDG}} \ln MedRes_i + \beta_{\text{RUSS}} \ln MedRes_i + \beta_{\text{RUS}} \ln R_{ex-94} + \beta_{\text{MED}} \ln MedRes_i + \beta_{\text{RUS}} \ln R_{ex-94} + \sum \beta_i T_i + \alpha_i + \epsilon_{it}$$

(7)

Both the FE and hybrid models are estimated for this functional specification. For the FE models, the parameter estimates for time-invariant variables automatically vanishes. For the hybrid formulation, the continuous variables are decomposed into group means and deviations from group means.

5. Results and discussion

5.1. Choice of fixed-effects model

Table 2 presents the results of the fixed-effects (within-effect) model, our main interest, for a number of different specifications. The first step, however, is to check whether we need to apply panel econometric techniques or whether a pooled model is sufficient. This can be done by conducting an F-test on whether all $\alpha_i$s are equal to zero (which would mean there are no significant HEI specific effect). For our primary Model FE1, $F(139, 1373) = 27.84$ ($p < 0.001$), which rejects the null that the $\alpha_i$s are zero at 99% confidence, clearly indicating the superiority of FE model, and as such panel econometric techniques. Hausman test for RE vs. FE also indicates a preference for the FE model ($\chi^2(17) = 237.7, p < 0.001$).

Within the FE models, several model specifications are tested in order to select the best-possible one. Our first interest is the choice of dependent variable: energy normalized using HDD (Model FE1 and FE2), or uncorrected energy as a dependent variable with HDD included as an explanatory factor (Model FE3). Clearly Models FE1 and FE2, which utilize normalized energy have significantly better fit (within-R² 0.413 vs. 0.313). As such all of the other models follow normalized energy as the dependent variable.8

Inclusion of energy prices requires some discussion. Energy prices are likely measured with some error (since we use one energy price for all HEIs, which varies only temporally) and inclusion of them in the model does not improve the model fit (Model FE1 vs. Model FE2). However, the parameter estimate for price becomes statistically significant, and also improves the significance of a few of the time fixed effects. Given the theoretical importance, we keep price in our model and also the time dummies to control for other time-dependent changes. As such Model FE1 is our preferred specification for the fixed effect model.9 Fig. 3 presents the model predictions with actual values for model FE1, and shows good visual fit of the model.

5.2. Choice of hybrid model

Technically, the hybrid model is an RE model, and we have already determined the appropriateness of FE over RE using statistical tests. Nonetheless, we run the hybrid formulation of the RE model to understand the effects of time-invariant characteristics. The choice of appropriate time-invariant characteristics such as membership in mission groups (e.g. Russell Group), research intensiveness (yes/no), focus on arts and social sciences or presence of a medical school is made via model fit performance. Given Russell Group and ex-G94 universities are all research intensive, and nearly all HEIs offering medical degrees are also research intensive, there is a very high correlation among these variables. There is also a negative correlation between a focus on arts/social sciences and research intensity, albeit not a strong one. The preferred hybrid model HY1 includes indicator (dummy) variables for membership in the Russell Group, in the ex-G94 Group, and research intensiveness as explanatory factors for between-effect differences. Also included is an indicator variable for three HEIs which are purely for medical research. Model HY2 is not too different, where the variables for Russell and ex-94 Group memberships are dropped, and is marginally inferior to Model HY1. Other specifications with characteristics such as presence of a medical school, and primary focus on arts or humanities subjects, do not improve model fit at all, because of the multicollinearity between the HEI characteristics.

Table 3 presents the results of the hybrid model. As discussed earlier, the parameter estimates on the mean-differenced variables are the within-effects. We indeed find that these estimates are the same as the FE parameters (Model FE1) above. The means of respective variables are time invariant and these parameter estimates represent between-

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8 Note that Model FE3 shows that an increase in HDD increases energy consumption only at 85% confidence level (parameter estimate 0.246). The somewhat weak significance is because in a fixed effect model only the temporal changes in HDD come into play, which becomes correlated with individual time effects.

9 We have also estimated a model without taking logarithms of the continuous variables, but that model performs poorly.
5.3. Effect estimates

The fixed effect model for temperature corrected energy use show that – within HEIs, over time – energy use increases with an increase in floor area, but the response is different with respect to residential and non-residential floor areas (Table 2, FE1). On average over all the HEIs, a 10% increase in non-residential floor space increases energy consumption by 3.2%, but a similar increase in residential floor area increases consumption by only 1.2%. This difference is expected given the multitude of energy-intensive uses of non-residential buildings (e.g., computing, heating of large spaces, research and teaching equipment, etc.). The less than proportional increase in energy consumption with respect to floor areas may indicate improved technical performance of the new buildings and/or the facilities therein (e.g., computers).

The effect of floor area is numerically slightly different when we consider within-HEI (temporal) and between-HEI effects. A 10% difference in mean non-residential floor area (i.e. the mean for each HEI over the years) is responsible for a 5.3% difference in energy use between different HEIs, while for mean residential space the difference is even less, at 1.8% (Table 3, HY1) – both of these effects are slightly larger than the respective within-HEI temporal effects (although not statistically significant). More importantly, both the between- and within-effect results point to the same qualitative conclusion that HEIs with larger floor space are more ‘energy efficient’ (use less energy per unit floor area) than those with smaller floor areas.

Note that the between-effect part of the hybrid model is conceptually similar to the cross-sectional models of carbon emissions from HEIs in the US by Fetcher [4] and Klein-Banai and Theis [5]. However both of them find that carbon emissions increase more than proportionally with respect to floor area. While recognising that carbon emissions and energy consumption are two different variables, this difference is worth considering. The potential discrepancy with our results arises most likely because the previous models did not include other correlated variables such as income or student and staff number. As such the floor space variables in those studies picked up the effects of not only floor area, but also income and number of occupants. As we explain in the next section, when we combine the different growth variables (floor area, income, occupants), we do not observe economies of scale in the cross-sectional analysis, supporting our explanation.

The effect of income on energy consumption requires further calculation because of the presence of the quadratic term in the model. The net effect of changes in income in the within-effect model is given by $\beta_{INC} + 2 \beta_{INCSQ} \ln INC$. Given the positive parameter estimate of
The parameter indicating whether an HEI is research intensive or not is positive and statistically significant at 99% confidence. This indicates that after controlling for income and size (which are generally large for research intensive HEIs), research intensive HEIs still consume 23% more energy compared to other HEIs. Clearly research activities – especially in the science, medicine and engineering domain – are often more energy intensive given the use of information technology services and other specialist energy-intensive equipment. After controlling for the research intensiveness, members of Russell or ex-G94 groups do not consume significantly more or less energy. The three medical research focused HEIs (MedRes) consume substantially more energy than their peers. For non-residential energy consumption (Model HY3-NR), the findings are similar: an increase in floor area and income increase non-residential energy consumption, increase in gas price reduces energy consumption. The effect of non-residential floor area on non-residential energy consumption is larger than the effect of non-residential floor area on overall energy consumption: this is expected given the variables

The statistically insignificant parameter estimate for occupant number is likely a result of multicollinearity, which is a known issue in this type of energy modelling, e.g. see Huebner et al. [52] for domestic electricity consumption. Our model fits better with all three growth variables, compared to only floor area and income.

\[ \beta_{\text{INCSQ}} \] indicates that the effect of income on energy consumption increases at larger incomes. At mean income of our estimation sample, a 1% change in income results in a 0.22% (std error 0.073) increase in energy consumption within the HEIs in the temporal dimension (Table 2, FE1). The parameter estimates for income in the between-effect part of the model are not too different from the within-effect part.

After controlling for income and floor space, the number of students and staff does not have a statistically significant within-effect on energy use in HEIs (Table 2, FE1). This is possibly not surprising as the student numbers rarely change substantially without concurrent changes in the physical size or income of the HEIs and the variables are highly correlated. Among published studies, Fatcher [4] reports an increase in carbon emissions with an increase in the number of students, but again, this specification does not control for the fact that universities with larger student populations are also larger in physical size. Also, Sekki et al. [24] looked into individual building energy consumption data from schools and found that the connection between energy consumption and occupancy was not strong.

Our main interest from the between-effect parameters of the hybrid model is in the impacts of the time-invariant characteristics of the HEIs, which cannot be determined from the FE or within-effect parameters.
now are more directly related.

5.4. Economies of scale

The parameter estimates above relate to a ceteris paribus condition, i.e. the parameters represent the effect of one variable keeping others constant. In reality, it is highly unlikely that one (e.g. income) will grow without an increase in another (e.g. the number of students). Given the recent growth and future growth strategy of most HEIs, it is important to understand the effect of future overall growth of HEIs on energy consumption. A relevant question is whether there are economies of scale in energy consumption, i.e. whether the HEIs become more 'energy efficient' as they grow over time. Given we have three variables that capture growth – namely floor area, income and number of occupants – we define economies of scale as the effect on energy consumption due to an increase in all of these factors simultaneously. It is important to consider the effect of these variables simultaneously because considering the effect of only one (as in parameters estimated in the previous section) would not represent overall growth correctly. This is equivalent to calculating $\beta_{\text{GIANR}} + \beta_{\text{GIAR}} + \beta_{\text{INC}}$ plus $+ 2 \beta_{\text{NCOR}} \cdot \ln{\text{INC}} + \beta_{\text{SC}}$. The combined effect of increasing these variables each by 1% is an increase in energy consumption of 0.63% (std. error 0.094). This indicates that energy consumption grows less than proportionally as the HEIs grow over time from their current position, i.e. there is an economies of scale effect in energy consumption in the temporal dimension. This may be because newer buildings (and the facilities and equipment within them) tend to be more 'energy efficient' than older ones.

The economies of scale within the HEIs in the temporal dimension does not necessarily mean that larger and wealthier universities (in terms of floor area, income and population) at the same point in time are less energy intensive compared to smaller ones. The between-effect part of the hybrid model reveals that a simultaneous 1% difference in all of the three growth indicators above results in a 1.05% (std. error 0.031) increase in energy consumption relative to the HEIs, indicating the absence of an economies of scale effect between the HEIs at a specific point in time.

The different findings in the temporal and cross-sectional dimensions show the usefulness of the hybrid models over the traditional cross-sectional models used before. The apparent contradiction between the economies of scale within HEIs as they grow over time and the lack thereof between HEIs at a specific time requires some consideration. From a mathematical point of view, it is driven by the larger estimates for each of the relevant between-effects compared to within-effects and opposing estimates for occupancy in Table 3. The underlying explanation may be linked to the temporalities of change in the sector, and the limitations of our dataset. As universities grow over time, they are likely to add energy-intensive new developments such as ancillary student facilities (e.g. sports halls, gymnasiums, swimming pools – which are relatively energy-intensive), but this may happen as a one-off event after the growth occurs, and not as a continuous process. Such ‘structural changes’ would have reduced the economies of scale, but might not be captured by the temporal dimension of our dataset, which only shows change that has occurred over the last decade – a relatively short and recent period of time. On the other hand, many universities in our dataset have existed for decades or even centuries related uncertainties in the higher education sector). Student and staff number and building floor area, however, do not grow as quickly as the HEIs (Table 2, FE1). This is a typical expectation from economic theory. A 10% increase in industrial gas prices reduces energy consumption by 2%, indicating energy use is relatively inelastic with respect to prices. Even the small price response can have an important role in understanding the recent reduction in carbon emissions in HEIs in England. BriteGreen [17] reports a 17% reduction in carbon emissions between 2005/06 and 2015/16. Given that real energy prices almost doubled during that period, at least a part of that emission reduction could be associated with the demand response to energy price increases. Fig. 4 compares the predictions from model FE1 with actual prices during that period with predictions assuming prices were the same as in 2002 (only a few HEIs are shown for the purpose of clarity). Clearly, energy use would have been higher (solid lines) had energy prices not gone up during the observation period. As such BriteGreen’s [17] projection that the English HEIs are set to reduce 23% of their emissions by 2020 (over 2005 emissions) may be optimistic if energy prices remain low in future. On the other hand, if prices go up in the future, emissions will likely be reduced further than projected.

Given the use of temporal fixed effects (the dummy variable FE1) in our model, it is not possible to ascertain whether the HEFCE carbon targets of 2010 had any role in reducing energy use. However, it is possible for the HEIs to reduce their carbon emissions without taking any measures at all since the carbon intensity of grid electricity in the UK has been declining over time. Similarly, reduction in carbon emissions is possible despite an increase in energy use if the carbon intensity of energy is reduced through greater use of renewable sources. As such the observed reduction in carbon emissions by BriteGreen [17] is not at odds with our findings of an increase in energy use.

5.6. Projections into the future

The model parameters of HE1 can be used to simulate future energy use from the higher education sector in the UK (similar to [50] for supermarkets). However such simulation is only as good as the underlying forecasts of the explanatory factors, which can themselves be quite uncertain. Therefore, instead of making forecasts of future energy use, we simulate future energy use in a hypothetical scenario of 4% growth in income per year for every HEI (average growth was 5.2% for our observations, we assume a conservative growth rate to reflect Brexit related uncertainties in the higher education sector). Student and staff number and building floor area, however, do not grow as quickly as income. As such we use a similar ratio of growth for these explanatory factors (Table 4). Given the uncertainty of future gas prices, they are kept fixed at the same value as in 2014. Fig. 5 presents the results from the simulation, which runs until 2027 and shows that energy consumption from the HEIs will continue to increase in the assumed conservative growth scenario if there are no external policy changes.

6. Conclusions

This paper set out to understand how changes in the HE sector can affect universities’ energy consumption by using the UK as a case study...
country. We discussed the limitations of existing studies that use cross-sectional regression models and argued that temporal information and ‘within-effect’ panel regression techniques are more suited to understanding the factors affecting energy use from HEIs and to answering the relevant policy questions – especially since researchers and policymakers are often interested in the evolution of energy use in the temporal dimension. The traditional limitations of FE models are resolved by applying a hybrid modelling technique to determine both ‘within’ and ‘between’ effects from the same model. Results show that the physical size of HEIs (building floor area) and income affect energy use directly, although student and staff numbers do not have a statistically significant effect due to multicollinearity. The effects of changes in non-residential and residential floor area are also different, reflecting different energy consumption patterns in different types of buildings. Increasing energy prices reduce energy use, a finding that indicates that the relatively slow growth in energy use and reduction in carbon emissions in recent years could be – at least partially – a result of increases in energy prices during that period. A fall in energy prices in future could therefore jeopardize reductions in energy use or carbon emissions from the HEI sector.

We observe some economies of scale in energy consumption in the temporal dimension: as HEIs grow over time, they become more ‘energy efficient’ (use less energy per unit of area, population or income). While testing of economies of scale is itself novel in this sector, this finding also has important implications. Unlike this work, all of the previous studies used cross-sectional data and reported scale ‘diseconomies’, and any forecasting or prediction exercise using those earlier studies would substantially overestimate energy consumption (or carbon emissions, as the majority of those studies investigate). The hybrid model also shows that research-intensive HEIs generally consume more energy compared to teaching-focused HEIs even after controlling for differences in income, floor area and student and staff population. Although these results are UK specific, the general direction of the effects of different variables will likely hold for other countries, too, especially for those where the higher education sector is still growing. This is certainly the case in many emerging and developing countries.

We stop short of providing any forecast for potential future energy use from HEIs given the uncertainties in the forecasts of other input variables in future. However, we do show how our model parameters can be used to predict energy use under an imagined future scenario. By varying the explanatory variables, the model can be used to explore other scenarios too; for example, a rise in fuel prices, a shift from research to teaching, or a drop in income or size of the universities. Clearly, the growth path of the HEIs and prices of energy are both quite uncertain and that uncertainty will be carried into such simulated scenarios, but that is a necessary evil in all forecasting models using multiple regression, as in here. The modest growth scenario (in income, built area and student and staff numbers) tested here suggests that energy use will continue to grow in future unless there is significant change in the policies currently driving growth in the HE sector in the UK.

The panel econometric modelling brings a step change in understanding how energy use in the HE sector evolves with changes in the underlying explanatory factors. The underlying panel econometric method can also be applied to other countries where such panel data is available. Similarly the method can be applied to carbon emissions if the underlying emissions data are available. However, there is still room for improvement. Incorporation of reliable and comprehensive data on building energy efficiency would further improve the current model. Most of the explanatory factors are highly correlated and modelling each of the explanatory factors as a function of other explanatory factors (e.g. space as a function of students and staff number) – possibly using a structural equation or energy decomposition framework (e.g. [51]) – could improve the understanding of the pathways to changes in energy use. Stochastic frontier methods could also be applied to benchmark the HEIs against those performing best on energy consumption. Such benchmarking results would be beneficial to individual HEI energy or sustainability managers.

Finally, by showing that universities’ income, size and research intensity are key influences on their energy consumption, this paper helps to build a picture of how non-energy policies (often invisible to policymakers and researchers) can contribute to escalating demand. The variations and changes in income, size and research intensity that are analysed here are not natural or inevitable, but are shaped and steered (among other things) by the policies of individual institutions and of wider cross-sectoral and national decision-makers. To date, these

<table>
<thead>
<tr>
<th>Table 4</th>
<th>2003</th>
<th>2014</th>
<th>Annual growth rate, %</th>
<th>Assumed growth rate for future, %</th>
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</thead>
<tbody>
<tr>
<td>Income (‘000 GBP)</td>
<td>146,990</td>
<td>238,870</td>
<td>5.21</td>
<td>4.0</td>
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<tr>
<td>Nonresidential area (m²)</td>
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<td>Residential area (m²)</td>
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<td>50,862</td>
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<td>0.6</td>
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<tr>
<td>Occupants</td>
<td>12,954</td>
<td>14,625</td>
<td>1.07</td>
<td>0.8</td>
</tr>
<tr>
<td>Energy-HDD normalized (‘000 kW h)</td>
<td>58,900</td>
<td>60,000</td>
<td>0.156</td>
<td>–</td>
</tr>
</tbody>
</table>
policies have mostly been (often unintentionally) driving energy demand in an upward direction. By revealing the role of institutional changes in escalating energy demand, the analysis here also supports the argument of Royston [54] for a new research and policy agenda that takes seriously the impact of invisible energy policies on energy demand.

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