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Students' use of virtual learning environment resources and their impact on student performance in an econometrics module

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We examine the relationship between students' engagement with a range of virtual learning environment resources and their module performance, focusing on a relatively large second year undergraduate econometrics module. The analysis offers a useful contribution to the literature on the relationship between virtual learning environment engagement and student performance through consideration of a broader range of virtual learning environment resources than is typically considered in analyses to date, also through using a wider range of control variables. The setting for the analysis is also of interest as data relate to the 2020/2021 academic year in which there was a greater onus on the provision of online learning resources. Further, while much literature considers student performance on economics principles modules, there is much less literature focusing on econometrics module performance. Results suggest that there are different relationships between virtual learning environment engagement and student performance, depending on the virtual learning environment resources under consideration. Generally, engagement with virtual learning environment resources that encourage more active learning is associated with better student module performance. Similarly, engagement with online formative assessments with immediate feedback is associated with student module success.

1. Introduction

In recent years, academics have made greater use of virtual learning environments (VLEs) to provide learning resources to students. This trend was amplified during the Covid pandemic as many

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universities were forced to rely on online teaching, or increasingly, blended learning. VLEs provide an excellent opportunity to provide diverse learning resources in an online environment that should be easy to access and navigate. A feature of VLEs is that data are typically easy to obtain on students' use of the online resources provided.

This article contributes to the literature on the value of VLE resources, specifically focusing on the relationship between accessing various VLE learning resources and student performance in a relatively large core quantitative module. The article provides an original contribution to this literature as it not only considers the relationship between different VLE learning resources and student performance, but a broader range of individual student controls are included than are typically used in this literature to date. Further, we believe that this is an early analysis of the relationship between VLE resources and student performance in an econometrics, rather than an economics, context. The relationship between engagement with VLE learning resources and student performance has been more typically analysed in core economics principles modules (Webb *et al.*, 2021). Economics principles modules focus on macroeconomics or microeconomics principles. Meanwhile, a basic econometrics module introduces students to regression methods that can be used to examine empirical relationships statistically.

The limited available literature provides mixed results on the impact of VLE use on student performance. Some suggest that additional learning resources increase students' cognitive burden, thus leading them not to engage with the resources (Wilson & Scalise, 2006). However, for content as challenging as econometrics to many students, the main issue an instructor faces is how to make sure that students with different levels of mathematical and analytical skills are learning the material before it is too late to impact their performance (Rajaram, 2011). Continuous learning and engagement are particularly crucial for student success in quantitative modules with studies suggesting that formative assessments such as online multiple-choice questions and exercise sheets reduce anxiety about the topic and help improve students' performance (Galle & Kukwi, 2020; Rajaram, 2011).

Thus, since VLE resources are of great value for continuous learning, it is important to examine which VLE resources have the most significant relationship with student module performance, not only in an academic year where the emphasis on online resources was so great but also considering that after the COVID pandemic many universities have decided to retain elements of blended delivery in their teaching and learning provision (Mullen *et al.*, 2021; Habala & Demlová, 2022). In the analysis below, we make use of the rich data on students' accessing of VLE resources that support a second-year undergraduate core econometrics module. As a core module, the module always has more than 300 students, but crucially, the module lecturers provide a wide range of learning resources on the module VLE, including topic notes, exercise sheets, discussion forums, past examination resources etc. Results discussed below sometimes contrast with those reported in the literature to date, highlighting the need to focus attention instead on student learning in a technical, econometrics module.

The results of our study offer an insight both to lecturers and students on the VLE resources which have the strongest association with student module performance, *ceteris paribus*. We also identify whether the use of various VLE resources has a differential impact on student attainment, according to student characteristics such as whether students are classed as UK/EU or other international students, and/or meet specific entry criteria to receive contextualized offers, including disability indicators. In supplementary results, we consider which student characteristics are associated with greater VLE engagement.

The remainder of the article is structured as follows: a literature review is provided in Section 2, while the materials and methods are presented in Section 3. Results are presented in Section 4, along with a discussion of any limitations of the research and possible directions for future research. Section 5 concludes.

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2. Literature review

The Covid pandemic has changed the university teaching and learning environment (Mullen *et al.*, 2021; Habala & Demlová, 2022). The move to online teaching offered a great opportunity to explore further the learning behaviour of students. Learner analytics data on VLE usage complements and enriches other information available on student engagement, giving rise to useful datasets to reflect on how different activities/resources available online may impact on students' attainment. This has important implications not only in terms of optimising the educational environment but also in creating opportunities for data-driven decision making for both lecturers and students (O'Sullivan *et al.,* 2021).

There is a vast literature, not restricted to economics, that analyses the impact of VLE resources on students' performance. In general, this literature lacks a consensus on the relationship between students' engagement and performance, partly because the definitions of student engagement differ (Boulton *et al.,* 2018). For example, student engagement may be considered as time spent online versus VLE entry logs. Also, results are context dependent and rely on the different types of VLE resources considered in the analyses. Further, studies adopt different evaluation methods, for example, self-reporting survey data versus revealed preferences approaches where student use of different VLE resources reveals how much they value them for their learning experience. Nevertheless, multiple studies have concluded that the use of VLE resources has a positive impact on students' performance by supporting active, continuous engagement and learning; providing self-assessment tools and module material; and providing faster feedback to students' queries via discussion forums (see for example, Calafiore & Damianov, 2011; Boulton *et al.*, 2018).

Various studies have assessed the effectiveness of engaging with chat functions/discussion forums on students' performance. Using a combination of survey data and VLE reports (namely Moodle entry logs), Lyndon & Hale (2014) conclude that discussion forums are popular among students, enhancing their learning experience and producing a positive impact on students' performance. Similarly, using the total number of words posted in forums as a measure of student engagement, Harmon & Tomolonis (2019) test the efficacy of forums in two different platforms, Facebook and the traditional VLE. The authors find that discussion forums on the traditional VLE system led to higher student engagement and performance; longer posts; and deeper thinking that reflected more student preparation and effort. However, Dutton *et al.* (2004) find that the use of VLE chat and discussion forums has no impact on students' preferences over face-to-face teaching and learning approaches. Furthermore, using time spent online as a measure of students' engagement with online discussions, Staveley-O'Carroll (2015) concludes that only female students perform better having participated in discussion forums.

Literature on the relationship between students' engagement with online quizzes and module performance has produced conflicting results to date. In a recent paper, Webb *et al.* (2021) focus on a cohort of intermediate economics students, finding no evidence that the provision of multiple-choice revision quizzes to test knowledge and understanding via the VLE is positively associated with students' performance. In line with results from Moffat & Robinson (2015)[1], the authors conclude that appropriate design of teaching material is also crucial for student engagement and performance, where students' engagement is captured here by students' quiz completion rates. Similarly, using completion of online quizzes as well as the duration of time spent working on them, Aljamal *et al.* (2015) conclude that there is no relationship between online engagement with quiz activities and students' performance in examinations. This result is also confirmed elsewhere in the literature (Harter & Harter, 2004;

[1] In their article, Moffat & Robinson (2015) consider quiz views and quiz attempts to measure the impact of revision quizzes on students' performance.

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Galizzi, 2010). However, Maclean & McKeown (2013) provide conflicting evidence. Using time spent on online quizzes as a measure of students' engagement, they find a strongly positive correlation between students' engagement and performance in an economics principles module.

Considering the impact of engagement with lecture recordings, Elliott & Neal (2016) conclude, in the context of a large first year microeconomics module, that viewing lecture recordings is a complement rather than a substitute for lecture attendance. A number of analyses also directly estimate the impact of watching lecture recordings on student performance in economics modules (Chen & Lin, 2012; Jones & Olczak, 2016). Chen & Lin (2012); Jones & Olczak (2016) identify positive, significant impacts of viewing lecture recordings on module performance, holding all else constant.

Our article contributes to and extends the literature in three ways. As in many papers to date (Gratton-Lavoie & Stanley, 2009; Williams *et al.,* 2016), we control for several student characteristics such as gender, nationality and academic performance. With changing student demographics in the university sector, it is vital to understand which resources enhance the learning process and to check whether different groups of students may benefit from different resources. Therefore, we broaden the literature by considering a wider range of socio-demographic student characteristics including ethnicity, disability and widening participation (WP) status (students identified as being from socio-economic groups under-represented in UK Higher Education), as well as previous exposure to economics. These are described in detail in Section 3. See Younger *et al.* (2019) for more detail on widening participation among students in a UK context.

We also consider a broader range of VLE resources than are typically considered in the literature to date. Many analyses focus just on the impact of engagement with formative assessments such as exercise sheets or quizzes, or discussion forums, on students' performance (Galle & Kukwi, 2020; Rajaram, 2011); or just on the impact of use of lecture capture (Chen & Lin, 2012; Jones & Olczak, 2016).

Further, our analysis adds to the literature by investigating the impact of the use of VLE resources on module performance in the context of a large, core econometrics module. To our knowledge, this has not been done. Pedagogy literature to date relating to econometrics modules typically highlights innovations and tools to support econometrics teaching (Kuroki, 2023). Arnold & Rowaan (2014) alternatively focus on overall first year undergraduate student performance, comparing the performance of students registered on economics versus econometrics degrees, while Galle & Kukwi (2020) look at student anxiety in the context of econometrics tests.

An assumption underpinning the analysis below is that student use of different VLE resources will reveal how much they value them for their learning experience, consistent with Elliott & Neal (2016); O'Sullivan *et al.* (2021).

3. Materials and methods

3.1 Context and data

The empirical analysis focuses on second year undergraduate student performance in a core econometrics module predominantly for students majoring in economics. The module may also be taken by a smaller number of joint degree students.

This module introduces undergraduate students to the ordinary least squares regression method and relevant diagnostic tests, before considering regression methods to deal with particular types of data such as panel data or time-series data.

Approximately 350 students took the module in 2020/2021. The module was partly selected because the module topics were little changed from previous academic years, with changes largely related to the updating of content. As such the lecturers had built up a large bank of VLE resources for students, and

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we were able to consider the impact of accessing a diverse range of module VLE resources on student performance.[2]

As with other modules during the pandemic, the weekly lecture mode of delivery changed from a 2-hour live face-to-face delivery to a 1-hour asynchronous lecture (delivered in 4 short 15-minute videos), which was made available to students prior to joining a 1-hour synchronous (live) online lecture, mainly used to recap material or for interactive discussion (for example, problem solving; theory applications and addressing discussion forum questions). The learning process was facilitated by weekly 1-hour online classes, each with around 17 students and supported by VLE resources such as discussion forums and formative online quizzes, designed to engage students with the learning material. Summative assessments took the form of 'open book' online tests and a final online three-hour examination. In the empirical analysis below, we exclude summative tests that contributed towards the final mark in the module as these were compulsory and so not indicative of student engagement levels[3].

We use Moodle log reports combined with Echo360 lecture capture learner analytics to gather information on students' engagement with the VLE. We combine this information with students' characteristics obtained from university student records[4] to quantify the impact of different levels of student engagement with VLE resources and characteristics on students' performance. This is measured as the final mark (out of 100) on the module.

We use count variables to quantify students' engagement with the VLE resources. Specifically, we consider the number of times a student viewed the different types of second year econometrics module VLE resources, including lecture capture recordings (on-demand views of lectures delivered both asynchronously and synchronously); topic notes; online quizzes; discussion forums; exercise sheets and past examination materials.

To this end, we apply consistent metrics in the analysis and define students' engagement as the number of times students viewed/had access to each VLE resource in the 2020/2021 academic year. As with other quantitative measures of studying effort (such as time spent online), the number of times a VLE resource has been accessed has its own limitations. For example, it is unable to capture the active or qualitative dimensions of studying effort (Hu & Li, 2017). Nevertheless, a large literature to date does use activity logs to measure students' engagement. For a review, see Mogus *et al.* (2012).

In terms of the VLE design, some of the activities encouraged a more active learning experience such as the online quizzes and discussion forums, compared to others including example lecture recordings and topic notes. The analysis aims to understand how the more active versus the more passive VLE resources may be associated with students' learning and module performance in the context of online learning.

Various controls are included that have been shown in previous studies to impact on individual student performance. It is important to control for prior attainment and this is done via a variable that indicates a student's prior performance across their first-year undergraduate economics modules.[5] Data were also available on the number of entry points that each student achieved to be accepted onto the degree.[6]

[2] The VLE used was, and continues to be, Moodle.

[3] The final mark on the module is a weighted average of all marks obtained in the module tests and final examination.

[4] We obtained ethical approval from the University of Warwick (HSSREC 193/20–21) to use these data for our empirical analysis.

[5] Note that first year module results do not contribute to a student's final degree result.

[6] This is similar to the Grade Point Average (GPA) variable regularly used in the literature. In the UK, entry points are often referred to as UCAS tariff points, where UCAS is the Universities and Colleges Admissions Service.

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However, there is little variability in this variable as the typical entry requirement for a student who had studied A levels in the UK in the cohort under consideration was A*, A, A including at least an A grade in A level Mathematics. As a result, we do not use entry points as a control variable. For similar reasons, we have decided to exclude from the analysis the control variable student age. The average age of the students included in the sample was 18.17 (standard deviation = 0.63). Other controls used include a gender dummy variable as, for example, Engelhardt *et al.* (2021) indicate gender differences in undergraduate student performance.

We also include dummy variables denoting students' UK/EU or international status; ethnicity; widening participation status and declared disabilities. See Table A1 for details. Previous analyses indicate that students with different characteristics might digest and benefit from module material in different ways. Students with dyslexia or international/non-native students might have greater returns from engagement with more passive VLE resources such as lecture recordings. These, in fact, might give them more control over their learning, thus having a positive impact on their learning outcomes (Williams *et al.*, 2016). Similarly, in recent years, the UK university sector has been under increasing pressure to increase diversity and inclusion. As a result, many high-ranking universities have seen a rise in the number of students coming from a widening participation background[7] and/or black, Asian and minority groups. Therefore, we control for such student characteristics that might influence students' performance, especially in light of recent research documenting various attainment gaps in the UK university sector (Advance, 2018; Boero *et al.*, 2024).

All variables included in the empirical analysis are detailed in the Appendix, in Tables A1 and A2. Table A1 and A2 provide a brief description of the variables, the expected signs of the coefficients associated with the various key explanatory and control variables and basic descriptive statistics. Approximately 36% of students in our sample are female; 3% are black and 12% are from widening participation backgrounds. Approximately half of the students in the sample have British nationality, with 10% coming from the EU and 39% from the rest of the world. Mean prior student performance, measured by average performance in first year core modules, was 68.25%.

The Appendix also includes the frequency distribution of VLE total engagement, i.e. the total number of times students accessed the VLE for the econometrics module under consideration. On average, students viewed the different VLE resources available in the econometrics module 4960.30 times across the academic year (29 weeks). See Fig. A1 in the Appendix for more information on the distribution of VLE usage. In line with the findings of Barile *et al.* (2022), some preliminary data analysis suggests that students were selective in their accessing of VLE resources, using them for certain topics and/or specific learning purposes. A closer look at students' total engagement with the VLE resources[8] indicates that students were more likely to engage with resources near to the dates of their online tests and final examinations. Active VLE resources such as discussion forums and formative online quizzes show a similar usage pattern of the total VLE engagement. If usage indicates revealed preference, our data suggest that these VLE features were highly valued by students as learning resources, especially during revision periods. Elliott & Neal (2016) reached a similar conclusion in the context of the use of lecture capture technology.

[7] In the empirical analysis below, widening participation students are students who joined the degree with contextual offers having met at least two contextual eligibility criteria from a range of 'contextual' factors (e.g., students living in neighbourhoods where the proportion of students going into higher education is low; students who completed their studies at schools/colleges where performance was below average; or students coming from an area with high levels of deprivation). Gorard *et al.* (2019) discuss common indicators for widening participation students.

[8] For the sake of brevity, data are not reported here, but can be made available from the authors upon request.

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Among other VLE resources, students favoured engagement with the past 2 years' examination material, remaining constantly engaged with topic notes and exercise sheets. Indeed, students may form expectations on examination content from previous academic years and this can be perceived as an important vehicle for communicating the relevance of certain skills and ability (Grogan, 2017).

There was one student outlier, namely a student who had 24,758 views of the VLE resources. The next highest number of views was 13,101 and this was not an obvious outlier. The outlying student was an international student and removed from the dataset before further data analysis. The final sample size is reduced to 209 as we have to restrict attention to the sample of students for whom data are available for all the control variables under consideration.

3.2 *Methodology*

A set of Ordinary Least Squares (OLS) cross-sectional regression models are developed to identify the relationship between students' engagement with various types of module VLE resources: lecture capture recordings; topic notes; online formative quizzes; discussions forums; exercise sheets and past examination materials and student module performance. We also control for a range of possible factors that may impact on student performance, such as prior attainment; gender; home/EU/international status; ethnicity.

$$\text{Performance}_{\text{i}} = \alpha + \sum_{\text{j}} \beta_{\text{j}} \text{VLE}_{\text{i,j}} + \sum_{\text{k}} \gamma_{\text{k}} \text{X}_{\text{i,k}} + \varepsilon_{\text{ijk.}}$$

where

Performance = module performance for student *i*, measured as a grade percentage on a scale of 0 to 100;

$VLE_{i,j}$ = a set of explanatory count variables of the number of times a student *i* has accessed a VLE module resource *j*;

$X_{i,k}$ = a set of control variables X_k for student *i*;

$\alpha, \beta_j, \gamma_k$ = coefficients estimated in the regression modelling;

ε_{ijk} = a randomly distributed error term.

The performance and VLE engagement variables are expressed in natural logs. Firstly, this allows for potential non-linear relationships between engagement with the VLE resources and student performance to be assessed in a linear model. Secondly, the use of natural logs means that the estimated coefficients can be expressed as percentage changes, and this facilitates a clearer interpretation of the responsiveness of module performance to changes in the use of VLE resources Regressions were also run with performance and VLE variables not logged. Results are very similar but the explanatory power of the reported regressions is slightly higher.[9] As well as running regressions for the full sample of students, we also run regressions separately for UK and EU based students and international students to test if the impact of engagement with VLE resources differs between these two groups of students. Regressions were run including an additional set of interaction terms, interacting the gender and ethnicity dummy variables to test further if there are significant differences in the impact of use of the various types of VLE resources on student performance for different subgroups of students.

All regressions are estimated with robust standard errors as Breusch-Pagan tests indicated, as expected, the presence of heteroskedasticity. Rather than running regressions with all the VLE engagement

[9] Results are withheld for the sake of brevity but of course available upon request.

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TABLE 1. *Regression Results*

Explanatory Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
lnTotal	0.0668**						
lnLecture		0.0163					
lnForum			0.0063				
lnNotes				0.0521**			
lnQuiz					0.0940***		
lnExercises						−0.0230	
lnExam							0.0258*
lnPastperformance	0.8085***	0.8499***	0.8609***	0.8274***	0.7853***	0.9078***	0.8271***
Female	0.0576	0.0719*	0.0691*	0.0694*	0.0455	0.0767**	0.0589
WP	−0.0601	−0.0511	−0.0525	−0.0588	−0.0550	−0.0496	−0.0600
Disability	−0.1039	−0.1160	−0.1085	−0.1092*	−0.1108*	−0.1156	−0.1153
EU	−0.0673*	−0.0713*	−0.0712*	−0.0702*	−0.0653*	−0.0813**	−0.0643*
International	−0.0274	−0.0317	−0.0361	−0.0272	−0.0218	−0.0446*	−0.0266
Chinese	0.0880**	0.0911**	0.0887**	0.0855*	0.0942**	0.0897**	0.0961**
Asian	0.0212	0.0180	0.0188	0.0253	0.0129	0.0112	0.0151
Black	0.1257**	0.1150**	0.1171**	0.1205**	0.1263**	0.1006**	0.1278**
Other	0.0426	0.0489	0.0416	0.0462	0.0484	0.0419	0.0464
Chinese∗Female	−0.0954	−0.1117*	−0.1095*	−0.1008*	−0.0926*	−0.1095*	−0.1029*
Asian∗Female	−0.1358*	−0.1430**	−0.1427**	−0.1477**	−0.1192*	−0.1392**	−0.1362*
Black∗Female	−0.3452***	−0.3351***	−0.3204***	−0.3645***	−0.3356***	−0.3122***	−0.3495***
Other∗Female	−0.0719	−0.0814	−0.0708	−0.0762	−0.0885	−0.0727	−0.0684
Constant	0.1485	0.4657	0.4572	0.2873	0.1254	0.4240	0.5614
N	209	209	209	209	209	209	209
R^2	0.3798	0.3653	0.3624	0.3800	0.4098	0.3704	0.3750

Notes: ***,**,* indicates a coefficient is significantly different from zero at the 1%, 5%, 10% levels, respectively. Robust standard errors are used.

variables included simultaneously as explanatory variables, regressions were run with each VLE engagement variable added separately. This was important as, again as anticipated, we found that there were relatively high correlations between students' use of the various types of VLE resources available, leading to concerns that multicollinearity might prevent us from estimating the impact of use of each type of VLE resource on student performance, *ceteris paribus.* See Appendix Table A3 for details of the correlations between the measures of VLE engagement.

4. Results

4.1 Main results

Regression results in Table 1 are initially presented for the full sample of undergraduate students taking the core second year econometrics module to identify the factors contributing to module success in terms of overall module mark.

The results reported in Table 1 indicate that engagement with VLE resources is positively and significantly associated with module performance. Considering all engagement with VLE resources *lnTotal*, engagement has a positive impact on module performance, significant at a 5% significance level, *ceteris paribus*. Looking at engagement with specific VLE resources, greater engagement with some but clearly not all VLE resources is associated with a significantly better module performance. In contrast to previous results (Harter & Harter, 2004; Galizzi, 2010), engagement with online quizzes is found to have a positive, significant impact on students' module performance, holding all else

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constant. A possible explanation for this seeming contradiction in the literature is that, compared to other subjects, an econometrics module requires more engagement with practical exercises to deepen students' understanding of the topics. Harter & Harter (2004) examined students' performance in an introductory economics module. Meanwhile, Galizzi (2010) considers student performance in one upper-level economics class and in two introductory economics classes when analysing the effectiveness of quizzes on students' learning experience. Furthermore, in the econometrics module considered in this article, the online quizzes took the form of multiple-choice question quizzes and similarly there were some multiple-choice questions as part of the students' summative assessments. Thus, students may have consciously decided to engage more with quizzes to practice for their summative assessments.

Engaging with topic notes and past examination information are also found to have a positive, significant impact on module performance, although with these resources having successively smaller significant impacts on module performance, holding all else constant. Watching lecture capture recordings is not found to have a significant, positive impact on student performance *ceteris paribus*. This contrasts with the results of Chen & Lin (2012). While in that study, the recordings were a complement to face-to-face lectures, in our study, the analysis covered the 2020/2021 academic year when no face-to-face lectures were delivered. Consequently, the lecture recordings were a substitute for and not a complement to face-to-face lectures.

Similarly, engaging with the VLE discussion forums and viewing exercise sheets are not found to impact significantly student performance, holding all else constant. The result that viewing exercise sheets to be discussed in seminars has no significant impact on student attainment is maybe not surprising, as what should be effective in student learning is the attempting of the exercise sheet questions. However, the data cannot measure the extent of student engagement with the exercise sheets uploaded by the module lecturers, only the number of times the exercise sheets have been viewed. In line with the results of Rienties & Toetenel (2016), our findings suggest that specific types of more active VLE learning resources such as online quizzes are of significance to enhance students' performance in quantitative modules.

There are further results worthy of comment in Table 1. First, note that inclusion of students' first year mean core economics module performance dominates the impact of engagement with VLE resources on student second year econometrics performance. This highlights the importance of controlling for student ability/past performance and maybe indicates the importance of students adapting to university study in the first year of their undergraduate degrees. Note that the result above holds, even though at the university under consideration students' first-year performance does not contribute to their final undergraduate degree results. First-year performance only affects the decision regarding whether a student can progress to the second year of undergraduate study. Regression results from regressions excluding this variable are similar except the coefficients on the various VLE engagement variables are typically significantly positive at higher significance levels. The coefficient associated with VLE topic notes engagement is now positive and significant at the 1% significance level, the coefficient on engagement with lecture capture recordings is now positively significant at the 5% level, while the coefficient associated with engagement with the discussion forums is significantly positive at the 10% level, *ceteris paribus*.[10]

Also note that widening participation students do not perform significantly differently to other students, and students with a self-declared disability at most perform significantly worse at a 10% significance level in Table 1, *ceteris paribus*. Nevertheless, some of the results associated with students of different ethnicities and particularly results for some categories of female students of non-white

[10] These results are withheld only for the sake of brevity and of course are available on request.

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ethnicities are of concern, particularly considering research into higher education attainment gaps (Boero *et al.*, 2024). However, we note that the sample sizes for some of the categories of non-white female students are very small and so results may not be generalizable.

Regressions were also run including interaction terms between each engagement variable and dummy variables that indicated whether a student was from the EU, or international (beyond the EU). Results confirmed that the coefficients on these interaction terms were typically insignificantly different from zero, *ceteris paribus*. The only coefficient significantly different from zero was that associated with the interaction term of engagement with VLE exercises and EU students. The coefficient associated with this variable was negative, but only different from zero at a 10% significance level.[11]

A limitation of the analysis above is that there were missing control variable values for a number of students which impacted on the final sample size. We also recognise that our variables measuring students' engagement with the various module VLE resources may not be perfect. To consider a large number of VLE resources consistently in the analysis, we are only able to measure engagement as the number of times any student views a VLE resource.[12] We hope that this is a useful guide as to which VLE resources students perceive as most valuable to their study, as well as being a simple measure of student VLE engagement. One can argue that a more precise measure of student VLE engagement may be the time spent accessing materials such as lecture recordings, online quizzes and discussion forums, Boulton *et al.* (2018). Nevertheless, for some VLE resources that students may choose to access, download and work with outside the VLE environment, for example topic notes and exercise sheets, data on time spent accessing the resources online may not be very useful. As suggested by Hu & Li (2017), mixed methods (i.e. quantitative and qualitative methods) may be combined to analyse students' learning processes and to better understand the multidimensional aspects of students' engagement, involving students' behaviour, cognition and emotions.

A limitation of our results is that our analysis relates to the 2020/2021 academic year when the cohort of students under consideration was limited to online study. As such, we accept that the results presented relating to the relationship between student engagement with various VLE resources and module performance may represent the maximum extent to which there is an association between these variables as students may have relied more heavily on VLE learning resources than they may otherwise do. Future research could repeat the analysis for an academic year in which students have opportunity for more in-person interactions.

Similarly, our results suggest a further area for potentially useful research may be a comparative analysis of the value to students of watching lecture recordings, distinguishing between whether lectures were provided in person or online. Previous research has indicated that, in an economics context, there may be small but significant positive effects on module performance of watching lecture recordings. In addition, recent research suggests that, for difficult topics, students watching lecture recordings perform better than those who attend live lectures (Artz *et al.*, 2022). However, these results relate to the viewing of face-to-face lecture recordings. Results above instead suggest that there may be no significant benefit of watching recorded online lectures. It suggests that such resources, experienced passively, are of no benefit in learning. Lecture recordings may only be beneficial if used as a complement to engagement at face-to-face lectures. This is an important area for further research.

11 These results are withheld only for the sake of brevity and of course are available on request.

12 Some of the activities/resources available on Moodle provide detailed information on time spent engaging with the activity (for example the online quizzes). However, this information is not available for all resources. Thus, we opted for a consistent measure of VLE engagement across activities, but also as adopted elsewhere in the literature (Mogus *et al.,* 2012).

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TABLE 2. *Student Engagement Results*

Explanatory Variable	All Students
lnPastperformance	0.9343***
Female	0.2159*
WP	0.1096
Disability	−0.1174
EU	−0.0946
International	−0.1696**
Chinese	0.0173
Asian	−0.0377
Black	−0.1621
Other	0.0088
Chinese Female*	−0.2336
Asian Female*	−0.0920
Black Female*	0.4487**
Other Female*	0.0069
Constant	4.5295***
N	209
R^2	0.1674

Notes: ***,**,* indicates a coefficient is significantly different from zero at the 1%, 5%, 10% levels, respectively. Robust standard errors are used.

4.2 Supplementary results

In Table 2, we instead consider the student characteristics associated with greater engagement with the various VLE resources. Hence, the dependent variable is now *InTotal*.

Two results from Table 2 stand out. First, those students who performed better in the first year of their undergraduate degrees engage more with the second-year econometrics VLE resources, *ceteris paribus*. Second, international students are significantly less likely to engage with the VLE resources, holding all else constant. This result is worrying and indicates that we should consider providing more guidance for international students regarding how to use the learning resources and the positive impact the use of VLE resources can have on their module performance, as indicated in Table 1.

5. Conclusions

In this article, we examine the relationship between students' engagement with a range of VLE resources and module performance, focusing on a relatively large second year undergraduate econometrics module. To date, pedagogy analyses have typically focused on student performance in economics principles modules rather than in more quantitative modules. This article is one of the few papers to consider students' engagement with learning resources in econometric modules. The analysis contributes to the literature on the relationship between VLE engagement and student performance through consideration of a broader range of VLE resources than are typically considered in analyses to date, and through using a wider range of control variables to capture student demographics. Data relate to the 2020/2021 academic year in which there was a greater onus on the provision of online learning resources, as much UK university education was confined to the online learning space because of the global pandemic.

Results above suggest that there are differential impacts of engagement with a range of VLE resources on student module performance. Generally, we conclude that engagement with those VLE resources that encourage a more active approach to learning such as online quizzes with immediate feedback are

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associated with better student module performance. This result can guide lecturers as to which VLE resources it is worth spending the most time developing.

Credit authorship contribution statement

Lory Barile: Conceptualization, Data validation and analysis, Investigation, Methodology, Software, Visualization, Writing—original draft, Writing—review & editing, support on project supervision and administration. **Caroline Elliott**: Conceptualization, Data validation and analysis, Investigation, Methodology, Software, Visualization, Writing—original draft, Writing—review & editing, Supervision, Project administration. **Michael McCann**: Visualization, Methodology, Writing—original draft, Writing—review & editing. **Zaharia Paul Pantea**: Preliminary data analysis, Visualization, Methodology.

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APPENDIX

TABLE A1. *Variable Details*

Variable Name	Variable Details	Expected Sign
lnPerformance	Natural log of final module mark	
lnTotal	Natural log of total VLE engagement	+
lnLecture	Natural log of recorded lecture views	+
lnForum	Natural log of discussion forum views	+
lnNotes	Natural log of topic notes views	+
lnQuiz	Natural log of online quiz views	+
lnExercises	Natural log of exercise sheet views	+
lnExam	Natural log of past examination views	+
lnPastperformance	Natural log of mean mark in core year 1 modules	
Female	Dummy variable = 1 indicates female student	+/−
WP	Dummy variable = 1 indicates widening participation student	−
Disability	Dummy variable = 1 indicates a student with a disability	−
EU	Dummy variable = 1 indicates a student from the EU	+/−
International	Dummy variable = 1 indicates an international student not from the EU	−
Chinese	Dummy variable = 1 indicates Chinese ethnicity	+/−
Asian	Dummy variable = 1 indicates Asian, not Chinese, ethnicity	+/−
Black	Dummy variable = 1 indicates black ethnicity	+/−
Other	Dummy variable indicating other, non-white, ethnicity	+/−

TABLE A2. *Raw Data Descriptive Statistics*

Variable Name[1]	Mean[2]	Standard Deviation	Min.	Max.
Performance (final mark)[3]	62.44	10.78	24	84
VLE engagement	4960.36	2009	1000	13,101
Lecture	96.93	47.99	0	260
Forum	471.89	402.94	10	1905
Notes	795.57	362.48	19	2480
Quiz	1643.09	720.6	191	3879
Exercises	280.86	170.3	1	1147
Exam	25.06	27.49	1	242
Past performance (average Year 1 marks)	68.25	7.94	45	88
Female students	0.36	-	-	-
WP students[4]	0.12	-	-	-
Disability Students	0.04	-	-	-
EU Students	0.1	-	-	-
International Students	0.39	-	-	-
Chinese Students	0.18	-	-	-
Asian Students	0.34	-	-	-
Black Students	0.03	-	-	-
Other Ethnicity	0.09	-	-	-

[1]VLE engagement variables consider the total number of times a student viewed the resource online. The sum of the engagement with different VLE resources is less than the total VLE engagement variable as this will include engagement with additional resources included in the VLE such as guides on how to use the resources.
[2]For dummy variables, values indicate the proportion of students in the relevant category.
[3]Student performance is measured as grade percentage on a scale from 0 to 100 and represented the weighted average of all module assessments.
[4]For WP students, the summary statistics have been calculated considering only Home students.

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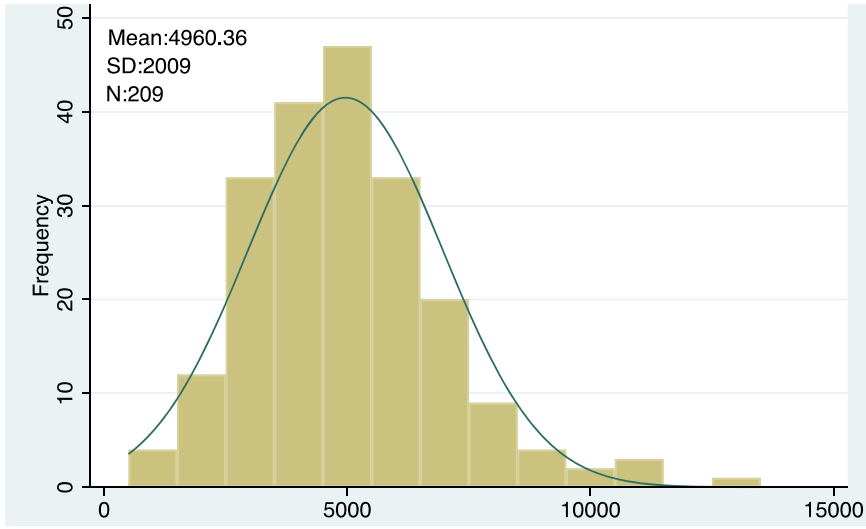

FIG. A1. Frequency distribution for total VLE engagement

TABLE A3. *VLE Engagement Correlation Coefficients*

	lnTotal	lnLecture	lnForum	lnNotes	lnQuiz	lnExercises	lnExam
lnTotal	1.0000						
lnLecture	0.5374	1.0000					
lnForum	0.7476	0.4127	1.0000				
lnNotes	0.8154	0.5289	0.5351	1.0000			
lnQuiz	0.8177	0.3963	0.4900	0.5060	1.0000		
lnExercises	0.6431	0.3708	0.6031	0.5572	0.3085	1.0000	
lnExam	0.6335	0.4323	0.4893	0.4637	0.5442	0.3579	1.0000

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