Economics and Finance in the MBA Core: Sequence of Core Course Completion and Student Performance

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Abstract

Does the order in which MBA students complete the core courses for the degree affect their performance in the program? There is little literature on this topic. To gain insight into this question, we examine 5,822 student/course records from a large public university for the years 2008-2012, encompassing part of the academic history of 1,384 MBA students. Standardized grades are our measure of performance in each of nine core courses. For each core course, both t-tests of differences in mean grade across different combinations of prior courses and fixed-effects OLS regressions indicate that the sequence of completing courses affects student performance. The Economics core course informs Accounting and Marketing, for example, while the core Finance course interacts with Management courses. While the data limit the strength of any conclusions, we find good indications for placing information systems and quantitative methods courses earlier in the core sequence.

Key words: MBA core, course sequencing, student performance

JEL: A12, A23, M10

Introduction

To determine the effect of MBA core course sequencing on MBA student performance, we examine 5,822 records of student performance in each of nine MBA core courses at Middle Tennessee State University, a large AACSB accredited regional university, during the Spring 2008 to Spring 2012 period. This includes partial performance records of over 1,384 individual MBA students. Student performance is defined as the standardized grade a student earns in a course, where the raw grade is standardized by subtracting from the mean grade given by that student's instructor in all sections of that particular core course.

Two different methods are employed to test for the effect of course sequence. The first uses t-tests to compare the mean grade earned in course B when course A is taken first against the mean grade earned in course B when course B is taken first. The second runs OLS regressions of course B grades against dummy variables indicating the other core courses taken prior to course B. The second method allows for control of other student characteristics, so that the effect on course B's grade is more likely due to course sequence than to differences in the kinds of students that choose a particular sequence.

The composite results of the two methods reveal some surprises. Information Systems Management is a valuable precursor to five other core courses directly, and indirectly to two more, while there are no core courses that positively affect it. The courses that benefit the most from other core courses are Managerial Economics (five) and Financial Analysis (four), followed

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by Marketing Management and Accounting for Business Decisions (three each). Oddly, the capstone Strategic Management course benefits from only two other core courses, one course directly and another indirectly. We present both our recommendations for sequencing as well as a comparison of the optimal sequence to the actual sequences in which students took courses during the period.

The paper is organized as follows. A literature review follows the introduction, then the data collection is discussed. A detailed discussion of the methodology and results is followed by a summary and conclusion.

Literature

Little literature relates MBA course sequencing to student performance in MBA programs. Several articles address the effect of prerequisites on performance in individual courses (MacMillan-Capehart and Adeyemi-Bello, 2008), the determinants of student success in individual courses (Krausz, et al. 2002), and the need for individual courses and their prerequisites in MBA programs (Kolluri and Singamsett, 2007). Others examine MBA admission elements and find (Christensen, Nance and White, 2012; Malik, 2011; Sulaiman and Mohezar, 2006; Truell, Zhao, Alexander and Hill, 2006) that undergraduate grade point average (GPA) is the best predictor of a student's MBA GPA, while GMAT quantitative score, performance in undergraduate composition courses, and certain undergraduate majors (especially economics and business statistics) positively influence MBA performance. The issue of overall sequencing of the MBA core courses and any possible effects on student performance due to differences in sequencing has not been addressed previously.

Nevertheless, Dailey (2011) points out that flexibility in MBA course sequencing – interpreted as lack of prerequisites or other sequencing requirements in the core - can be a marketing advantage for MBA programs, especially part-time programs. An examination of websites for competing MBA programs in Tennessee reveals a range of sequencing requirements from minimal prerequisites (MTSU, University of Memphis) to limited prerequisites (ETSU, Belmont and Lipscomb Universities) to strict sequencing (UT-Knoxville, Vanderbilt University). This is mirrored in MBA programs at institutions in neighboring states such as the University of Alabama – Tuscaloosa (minimal) and the University of Kentucky (strict sequencing). Thus, the degree to which core courses are required to be completed in sequence appears to be one component of an MBA program's product niche.

All of this taken together suggests that MBA core sequencing requirements should not be adopted solely on the basis of student performance as measured below. Sequencing requirements are part of an MBA program's product niche and should be adopted to serve consumers to whom the chosen product niche appeals. Any choice of sequencing requirements is likely to involve trade-offs among attraction of students to the program, student performance in specific courses, and the ability of students to complete the program.

Data

We obtained data comprising all students taking courses in the Jones College of Business at Middle Tennessee State University from Spring 2008 to Spring 2012. Each record contains an instructor ID, days and times at which the course met, basic demographic information on the student (birthdate, ethnicity, sex), information on previous college and high schools attended (including GPA), and test scores (ACT, SAT, GMAT, GRE).

Not all of the data were usable. Among the problems were students with several different assignments of ethnicity or sex, birthdates after 2011, or extreme outliers for high school GPAs or test scores. We deleted all records for students with obviously bad data. We concluded that the most reliable variables were those that appear on student transcripts: semester, course, and grade.

Our final dataset contains 124,840 records, with each record containing the grade for a specific course taken by a specific student in a specific semester. We extracted all records in which the course taken was one of nine core MBA courses. Since our main interest is in course sequencing, we dropped all students who took a particular course more than once. The result was 5,506 records that represent a portion of the academic history of 1,350 students. This dataset contains relatively few complete MBA student histories: only 40 students took all nine core courses during the sample period. Another 235 students took eight core classes, but many of these may be students with Accounting or Information Systems undergraduate degrees who are required to take only eight of the nine core classes. Most of the students either began taking courses before our sample period, or were still unfinished at the end. The short span of the sample period limits our analysis to semester-to-semester comparisons.

Table 1: Frequency of core courses in dataset

Course	Description	incidents
ACTG.6910	Accounting and Business Decisions	207
ACTG.6920	Financial Statement Analysis	366
BUAD.6980	Strategic Management	550
ECON.6000	Managerial Economics	706
FIN.6710	Financial Analysis	594
INFS.6610	Information Systems Management and Applications	660
MGMT.6600	Study of Organizations	765
MGMT.6650	Operations Management	672
MKT.6800	Marketing Management	763
QM.6770	Computer-Based Decision Modeling	223
Total		5506

Table 1 shows the frequency with which each core course occurs in the dataset. There are ten courses listed, because students can take either of the two accounting courses. The low frequency for the QM 6770 course is due to its relatively recent addition in the core.

Methods

Our objective is to determine whether taking course A before course B will improve student performance in course B. We define student performance as the grade a student earns in course B, where that grade is standardized by subtracting from it the mean grade given by that student's instructor in all sections of that particular core course in that particular semester. This controls for differences in grades across instructors.

We use two different methods to investigate this question. The first employs t-tests to compare the mean grade earned in course B when course A is taken first with the mean grade earned in course B when course B is taken first or when A and B are taken at the same time. The second method uses OLS to estimate a model with course B grades as the dependent variable and dummy variables indicating which other core courses were taken prior to course B. The advantage of the second method is that it allows us to control for other characteristics of students, so that we can be more certain that the effect on course B's grade is due to course sequence, and not simply to differences in the kinds of students that choose a particular course sequence.

Table 2 reports the information used to calculate the t-statistics that underlie Figure 1. The top matrix gives the number of incidents in which a student takes the row course before the column course. The second matrix reports the mean grade in the column course for those taking the row course first, minus the mean grade in the column course for those *not* taking the row course first. The third matrix presents a p-value for a t-test applied to each group, with the null hypothesis that taking the row course before the column course will result in the same grade in the column course as not taking the row course first. We use the Welch t-statistic, for comparing two means with different variances (Welch 1947), which requires degrees of freedom produced using the Welch-Satterthwaite equation (Satterthwaite 1946). The last matrix is an adjacency matrix, where the non-zero entries represent cells for which the p-values are less than 0.1: "1" indicates that taking the row course first improves the column course grade; "-1" indicates that taking the row course first lowers the column course grade.

Table 2: Data and results for t-tests

course	description	ACTG.6910	ACTG.6920	ECON.6000	FIN.6710	INFS.6610	MGMT.6600	MGMT.6650	MKT.6800	QM.6770	BUAD.6980
Number of incidents of students taking row course before column course											
ACTG.6910	Accounting and Business Decisions	0	4	70	98	71	63	86	78	13	111
ACTG.6920	Financial Statement Analysis	1	0	112	160	97	100	137	97	49	229
ECON.6000	Managerial Economics	44	130	0	257	192	179	264	199	66	393
FIN.6710	Financial Analysis	30	76	135	0	122	128	177	127	52	382
INFS.6610	Information Systems Management and Applications	31	88	146	168	0	147	188	145	51	330
MGMT.6600	Study of Organizations	59	133	242	271	229	0	317	217	70	405
MGMT.6650	Operations Management	42	82	164	200	150	123	0	134	57	382
MKT.6800	Marketing Management	56	134	241	287	226	204	303	0	79	388
QM.6770	Computer-Based Decision Modeling	10	14	33	28	11	27	32	28	0	46
BUAD.6980	Strategic Management	3	2	4	3	1	1	2	0	1	0
Difference in mean standardized grades (those taking row course first minus all others)											
ACTG.6910	Accounting and Business Decisions	-	0.0132	0.0614	0.0159	-0.0445	0.0445	0.0591	-0.0503	0.1252	0.3701
ACTG.6920	Financial Statement Analysis	1.7607	-	-0.0149	0.0057	-0.1582	-0.1047	-0.0070	0.0352	-0.0721	-0.1003
ECON.6000	Managerial Economics	0.3232	0.0176	-	0.0061	-0.0229	-0.0089	-0.0326	0.0585	-0.0050	0.1730
FIN.6710	Financial Analysis	0.1442	0.0470	0.0587	-	0.0556	0.0777	0.0993	0.0016	0.1019	0.1073
INFS.6610	Information Systems Management and Applications	0.2985	0.0918	0.0983	0.0354	-	0.0525	-0.0284	0.0913	-0.1554	0.1344
MGMT.6600	Study of Organizations	-0.0939	0.0312	-0.0827	-0.0348	-0.0005	-	-0.0014	0.0755	-0.0461	0.0366
MGMT.6650	Operations Management	0.1827	0.0023	-0.0119	0.1467	-0.0711	0.0045	-	0.0631	-0.1800	-0.1083
MKT.6800	Marketing Management	0.1171	-0.0016	0.0021	0.0520	-0.0624	-0.0837	0.0249	-	0.1367	-0.1071
QM.6770	Computer-Based Decision Modeling	-0.0323	0.0731	0.0716	0.0136	0.0487	-0.0892	0.1477	-0.0007	-	0.0585
BUAD.6980	Strategic Management	-0.5989	-0.2013	-0.2740	-0.1465	-0.7048	-0.8730	-0.4352	-	0.0720	-
P-values for Welch's t-test (H0: Mean of row before column no different from all others)											
ACTG.6910	Accounting and Business Decisions	-	0.4847	0.2445	0.4452	0.2828	0.3116	0.2081	0.2271	0.2792	0.0098
ACTG.6920	Financial Statement Analysis	-	-	0.4122	0.4681	0.0088	0.0716	0.4481	0.2823	0.3588	0.2317
ECON.6000	Managerial Economics	0.0089	0.3399	-	0.4492	0.3290	0.4206	0.1720	0.0449	0.4840	0.0402
FIN.6710	Financial Analysis	0.1370	0.1755	0.1273	-	0.1736	0.0498	0.0060	0.4851	0.2306	0.0610
INFS.6610	Information Systems Management and Applications	0.0160	0.0261	0.0430	0.2440	-	0.1531	0.2339	0.0146	0.1328	0.0955
MGMT.6600	Study of Organizations	0.2438	0.2826	0.0420	0.2540	0.4954	-	0.4880	0.0362	0.3630	0.3522
MGMT.6650	Operations Management	0.0863	0.4793	0.4120	0.0036	0.1037	0.4626	-	0.0741	0.0726	0.0530
MKT.6800	Marketing Management	0.1947	0.4873	0.4836	0.1749	0.1011	0.0560	0.2789	-	0.1514	0.1007
QM.6770	Computer-Based Decision Modeling	0.4709	0.2567	0.2984	0.4546	0.3440	0.2764	0.0141	0.4969	-	0.3241
BUAD.6980	Strategic Management	0.0356	0.3445	0.0464	0.3276	-	-	0.2185	-	-	-
Adjacency Matrix (1==first taking row course improves grade in column course; -1=first taking row course harms grade in column course)											
ACTG.6910	Accounting and Business Decisions	0	0	0	0	0	0	0	0	0	1
ACTG.6920	Financial Statement Analysis	0	0	0	0	-1	-1	0	0	0	0
ECON.6000	Managerial Economics	1	0	0	0	0	0	0	1	0	1
FIN.6710	Financial Analysis	0	0	0	0	0	1	1	0	0	1
INFS.6610	Information Systems Management and Applications	1	1	1	0	0	0	0	1	0	1
MGMT.6600	Study of Organizations	0	0	-1	0	0	0	0	1	0	0
MGMT.6650	Operations Management	1	0	0	1	0	0	0	1	-1	-1
MKT.6800	Marketing Management	0	0	0	0	0	-1	0	0	0	0
QM.6770	Computer-Based Decision Modeling	0	0	0	0	0	0	1	0	0	0
BUAD.6980	Strategic Management	-1	0	-1	0	0	0	0	0	0	0

Notes to Table 2: Standardized grades are grades received by students minus the mean grade given by that particular instructor in that particular course in that particular semester. The t-test is the Welch t-test for comparing two means with different variances (Welch 1947). The adjacency matrix takes on values of 1 when the row course, taken first, significantly improves the grade in the column course; it takes on values of -1 when it significantly lowers the column course grade.

This adjacency matrix is presented graphically in Figure 1, considering only the positive values that represent grade improvement.

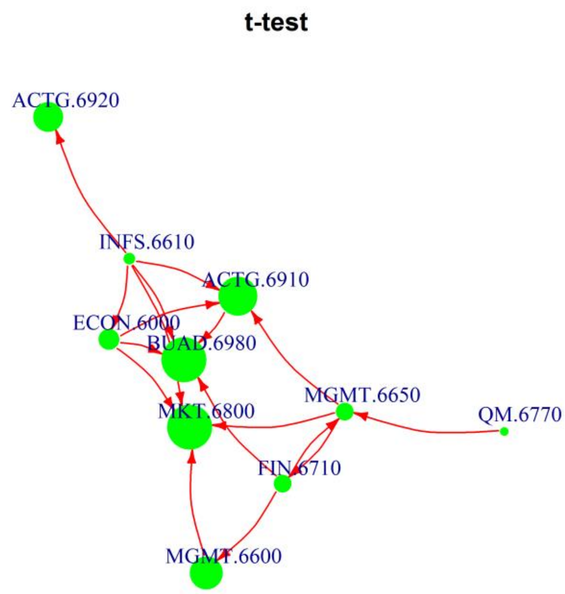

Figure 1. Graph derived from t-test adjacency matrix (Table 2). Arrows point from the course occurring first to course receiving the grade improvement. Larger vertices are more "reachable", while smaller vertices do more "reaching".

Table 3 reports descriptive statistics for variables used in regressions. We used the demographic controls age, sex, and ethnicity, despite our awareness that these data may not be accurate. The test score variable ("verbal" and its square) were constructed by standardizing (subtract mean, divide by standard deviation) each verbal test score across the entire sample of students (including undergraduates) and then taking the mean of the verbal and quantitative scores for each student. This procedure allowed us to avoid the problem of missing values in the GMAT scores. We also introduced a variable to capture whether students perform better in courses more aligned with their interests ("ownmaj"), as well as a dummy to indicate an online course. The variables of interest are the dummy variables indicating whether a specific core course was taken prior to the course represented in the observation.

Table 3: Variables used in OLS

variable	description	n	mean	sd	min	max
grnorm	Standardized course grade	5506	0.009	-3.846	1.567	0.589
eA	Asian	5506	0.092	0	1	0.288
eB	Black	5506	0.128	0	1	0.334
eW	White	5506	0.679	0	1	0.467
male	male	5506	0.609	0	1	0.488
age	age	5506	27.477	20	60	5.984
age2	age squared	5506	790.809	400	3600	399.498
verbal	composite verbal score	5197	-0.009	-2.084	2.721	0.959
verbal2	composite verbal score squared	5197	0.92	0	7.403	1.115
ownmaj	course is in students major	5506	0.109	0	1	0.312
online	online course	5506	0.173	0	1	0.378
ACTG.6910	Accounting and Business Decisions	5506	0.108	0	1	0.31
ECON.6000	Managerial Economics	5506	0.313	0	1	0.464
FIN.6710	Financial Analysis	5506	0.223	0	1	0.416
INFS.6610	Information Systems Management and Applications	5506	0.235	0	1	0.424
MGMT.6600	Study of Organizations	5506	0.353	0	1	0.478
MGMT.6650	Operations Management	5506	0.242	0	1	0.429
MKT.6800	Marketing Management	5506	0.348	0	1	0.476
QM.6770	Computer-Based Decision Modeling	5506	0.042	0	1	0.2
BUAD.6980	Strategic Management	5506	0.003	0	1	0.055

Table 4 reports the regression results underlying Figure 2. For each regression, the dependent variable is the grade earned in a particular course. In the top part of Table 4, columns give the names of the courses providing the dependent variable. The rows represent independent variables and cells show the standardized coefficients of independent variables that survived a stepwise procedure. Standardization allows comparison of effect sizes across variables, since the coefficient represents the number of standard deviations the dependent variable will change in response to a one standard deviation chance in the independent variable. Standard errors were obtained via bootstrapping (500 repetitions).

The second panel in Table 4 partitions R2 (Chevan and Sutherland 1991; Gromping 2006) across four different groups of independent variables. The variables composing each group are identified in the first column of the first panel. Course sequence accounts for a respectable share of variation in the dependent variable, sometimes exceeding the variation attributed to individual demographic or academic characteristics.

Two of the models (ACTG.6920 and INFS.6610) had relatively poor fits with the existing data, but the others performed well on the diagnostics (shown in the third panel of Table 4). Note that in all cases except for course INFS 6610, we can reject the null hypothesis that taking preceding courses has no effect on course grade.

At the bottom of Table 4 is an adjacency matrix giving the signs for significant (p-value ≤ 0.10) coefficients for preceding courses. Note that in six cases, taking course A before course B actually did damage, leading to a lower grade. Figure 2 shows a graphical representation of the adjacency matrix, omitting the negative entries.

The two methods provide slightly different results, so we take the intersection of the adjacency matrices in Tables 2 and 4 to create a composite adjacency matrix, dropping the negative entries. This provides a relatively robust view of sequencing effects. Figure 3 shows a graphical representation of the composite adjacency matrix.

Table 4: Results for regression on grades for each of the core courses

			Dependent variables: Standardized grades for the course									
group	variable	description	ACTG.6910	ACTG.6920	ECON.6000	FIN.6710	INFS.6610	MGMT.6600	MGMT.6650	MKT.6800	QM.6770	BUAD.6980
IDC	eA	Asian				0.1394***	-0.0707					
IDC	eB	Black			-0.2380***	-0.0930**	-0.0910**	-0.1329***	-0.1656***	-0.1755***		-0.1637***
IDC	eW	White	0.1627**		-0.1277**							
IDC	male	male		0.0907	0.0548		-0.0783*	-0.0531				-0.0833*
IDC	age	age	0.3404	-0.3692	0.0069	-0.2992	0.0410	-0.0517	-0.2149	0.1508	-0.0638	-0.0469
IDC	age2	age squared	-0.1423	0.4272	0.0180	0.3254	0.0586	0.0522	0.2219	-0.1427	-0.065	0.0598
IAC	verbal	composite verbal score	0.2202***	-0.0167	0.1666***	0.0482	0.1213***	0.0077	0.0037	0.1221***	0.2072***	0.1795***
IAC	verbal2	composite verbal score squared	0.0213	-0.0683	0.1351***	0.0861**	-0.0445	0.0185	0.0197	-0.0546*	0.04	-0.0176
OCC	ownmaj	course is in students major			0.1169***							
OCC	online	online course									-0.1296	
S	ACTG.6910	Accounting and Business Decisions								-0.0591*		
S	ECON.6000	Magerial Economics	0.1278*							0.0796**		
S	FIN.6710	Fincial Alysis			0.0674**			0.0890***	0.1154***			
S	INFS.6610	Information Systems Magement and Applications	0.1825**	0.1101**				0.0571		0.0693**	-0.1365*	-0.0748
S	MGMT.6600	Study of Organizations	-0.1834**									0.0782*
S	MGMT.6650	Operations Magement				0.1066***	-0.0688				-0.1374*	
S	MKT.6800	Marketing Magement						-0.0947**			0.2371***	
S	QM.6770	Computer-Based Decision Modeling	0.1143		0.0635**				0.0767***	0.0542*		
S	BUAD.6980	Strategic Magement						-0.0580***				

	Decomposition of R2		ACTG.6910	ACTG.6920	ECON.6000	FIN.6710	INFS.6610	MGMT.6600	MGMT.6650	MKT.6800	QM.6770	BUAD.6980
S	sequencing		0.0717	0.0111	0.0077	0.0114	0.0044	0.0175	0.0190	0.0198	0.0463	0.0067
OCC	other course characteristics		0.0000	0.0000	0.0121	0.0000	0.0000	0.0000	0.0000	0.0000	0.0139	0.0000
IAC	individual academic characteristics		0.0615	0.0039	0.0511	0.0131	0.0184	0.0008	0.0008	0.0183	0.0404	0.0336
IDC	individual demographic characteristics		0.0873	0.0122	0.0441	0.0358	0.0253	0.0193	0.0285	0.0323	0.0150	0.0311

	Model diagnostics		ACTG.6910	ACTG.6920	ECON.6000	FIN.6710	INFS.6610	MGMT.6600	MGMT.6650	MKT.6800	QM.6770	BUAD.6980
N		Number of observations	197	345	657	560	633	725	634	720	207	519
R2		Model R2	0.2200	0.0270	0.1150	0.0600	0.0480	0.0380	0.0480	0.0700	0.1150	0.0710
RESET pval		H0: model correct functional form	0.8812	0.2976	0.0649	0.2186	0.0287	0.1676	0.4900	0.5230	0.4067	0.1957
model F pval		H0: none of the independent variables significant	0.0000	0.1537	0.0000	0.0000	0.0001	0.0021	0.0001	0.0000	0.0018	0.0000
restr F pval		H0: dropped variables not significant	0.7912	0.9972	0.5235	0.6078	0.0003	0.5449	0.5606	0.6541	0.7231	0.9985
seqDummies F pval		H0: course sequence not significant	0.0042	0.0308	0.0074	0.0059	0.1215	0.0000	0.0000	0.0000	0.0081	0.1366

	Adjacency Matrix		ACTG.6910	ACTG.6920	ECON.6000	FIN.6710	INFS.6610	MGMT.6600	MGMT.6650	MKT.6800	QM.6770	BUAD.6980
	ACTG.6910	Accounting and Business Decisions	0	0	0	0	0	0	0	-1	0	0
	ACTG.6920	Financial Statement Analysis	0	0	0	0	0	0	0	0	0	0
	ECON.6000	Managerial Economics	1	0	0	0	0	0	0	1	0	0
	FIN.6710	Financial Analysis	0	0	1	0	0	1	1	0	0	0
	INFS.6610	Information Systems Management and Applications	1	1	0	0	0	0	0	1	-1	0
	MGMT.6600	Study of Organizations	-1	0	0	0	0	0	0	0	0	1
	MGMT.6650	Operations Management	0	0	0	1	0	0	0	0	-1	0
	MKT.6800	Marketing Management	0	0	0	0	0	-1	0	0	1	0
	QM.6770	Computer-Based Decision Modeling	0	0	1	0	0	0	1	1	0	0
	BUAD.6980	Strategic Management	0	0	0	0	0	-1	0	0	0	0

Notes to Table 4: Stepwise regression, showing standardized coefficient for final restricted model. Bootstrapping used to produce standard errors (* p-value≤ 0.1; ** p-value≤ 0.05; *** p-value≤ 0.01). Adjacency matrix shows sign of all course dummy coefficients with p-value≤ 0.1.

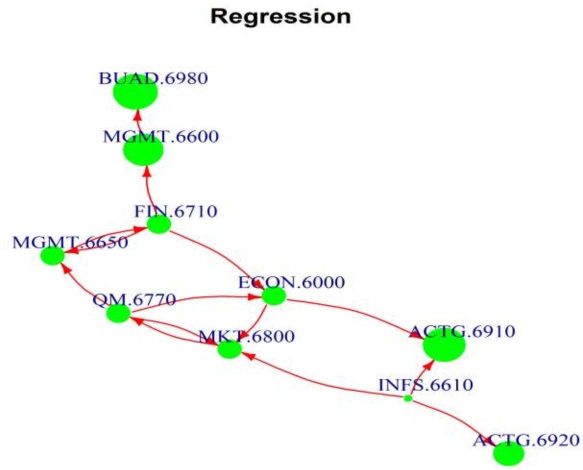

Figure 2. Adjacency matrix from dummies in regressions. Arrows point from the course occurring first to course receiving the grade improvement. Larger vertices are more "reachable", while smaller vertices do more "reaching".

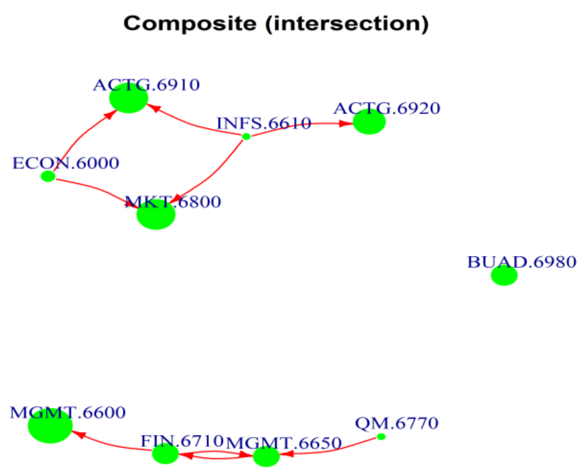

Figure 3: Composite optimal sequences, based on the intersection of graphs in Figure 1 and Figure 2. Larger vertices are more "reachable", while smaller vertices do more "reaching".

Table 5 shows the shortest path lengths between vertices in Figure 3. Some courses are clearly more connected than others: MGMT 6600, for example, receives links directly from 1 course and indirectly from two others.

Table 5: Shortest path length between vertices in composite graph shown in Figure 3.

course	description	ACTG.6910	ACTG.6920	ECON.6000	FIN.6710	INFS.6610	MGMT.6600	MGMT.6650	MKT.6800	QM.6770	BUAD.6980
ACTG.6910	Accounting and Business Decisions	0	0	0	0	0	0	0	0	0	0
ACTG.6920	Financial Statement Analysis	0	0	0	0	0	0	0	0	0	0
ECON.6000	Managerial Economics	1	0	0	0	0	0	0	1	0	0
FIN.6710	Financial Analysis	0	0	0	0	0	1	1	0	0	0
INFS.6610	Information Systems Management and Applications	1	1	0	0	0	0	0	1	0	0
MGMT.6600	Study of Organizations	0	0	0	0	0	0	0	0	0	0
MGMT.6650	Operations Management	0	0	0	1	0	2	0	0	0	0
MKT.6800	Marketing Management	0	0	0	0	0	0	0	0	0	0
QM.6770	Computer-Based Decision Modeling	0	0	0	2	0	3	1	0	0	0
BUAD.6980	Strategic Management	0	0	0	0	0	0	0	0	0	0

In the jargon of graph theory, MGMT 6600 is *reachable* by 3 other courses. Since we interpret each directed edge as indicating knowledge from the origin course is important for learning in the destination course, then a vertex that is highly reachable is one which builds on much prerequisite knowledge. Other courses are not reachable, but themselves reach, as for example INFS 6610, which sends links directly to 3 courses. Reachability provides one way to think about optimal course sequencing: highly reachable courses, which don't reach much or at all, should come last in the course sequence. One way to operationalize this is the following:

$$\text{reachratio} = \sum_j x_{ij} - \sum_i x_{ij} \qquad (1)$$

where **X** is a square matrix, where x_{ij} =1 indicates that a path connects vertex i to vertex j, and x_{ij} =0 indicates that vertex i cannot reach vertex j. In other words, *reachratio* is simply the column sums minus the row sums.

Figure 3 shows that, in this most robust version, no courses reach the capstone course BUAD 6980. It is odd that material from earlier courses provides no advantage to students taking the capstone. There are two possible reasons for this missing connection: first, the course content of the capstone might fail to utilize material from earlier courses; second, the earlier courses might fail to provide students with the tools needed to suceed in the capstone. Both explanations suggest a failure of MBA faculty to interact each other in integrating their courses into a coherent cumulative learning process.

Actual Course Sequencing

There is no single course sequence adhered to by most students at this institution, but some course sequences are more common than others. The first complication is that students take multiple courses each semester, so that a precise sequence from one course to another is never possible. Table 6 shows that about one out of three faces in an MBA class belongs to a student who is taking at least three core courses simultaneously in the same semester.

Table 6: Number of core courses taken in same semester

Number of core courses taken in semester	Number of occurances	Number of course seats	Percent of course seats
1	1960	1960	36%
2	1105	2210	40%
3	359	1077	20%
4	61	244	4%
5	3	15	0%
Total	3488	5506	100%

Table 7 lists the courses most commonly taken together—all dyads and the most common triads. The lists are sorted, so that the most frequently associated courses are at the top. When at least two of the associated courses are linked in Figure 3, the columns labeled "opt" indicate that relationship with the numeral "1". One can see that many of the courses taken together are identified as courses where improvement in one can be achieved by taking the other in an earlier semester.

A rough view of actual course sequences can be produced using the top matrix in Table 2 ("number of incidents of students taking row course before column course"). A course with a high column sum is *preceded by* many other courses; if it has a high row sum it *precedes* many other courses. We use the same calculation expressed in Equation 1 above, subtracting the row sum from the column sum. Courses with high values come later in the sequence.

Table 8 presents the sequences calculated from Equation 1, both actual (using the top matrix in Table 2), and three versions of an optimal sequence, based on Figures 1 through 3. Table 8 presents the ranks, rather than raw values, for each of these with some ties for the optimal sequences.

If one were to make recommendations based on Table 8, the most defensible are to push INFS 6610 and QM 6770 earlier in the course sequence. Looking at Economics and Finance specifically, Managerial Economics has been taken at about the right place in the sequence, while Financial Analysis is shown to have been taken a little too late. The first three courses generally taken by students (ACTG 6910, MGMT 6600, and MKT 6800) appear to be better placed near the end of the sequence.

Table 7: Courses taken in the same semester

All dyads				Most frequent triads				
course A	course B	occurrences	opt	course A	course B	course C	occurrences	opt
MGMT.6600	MKT.6800	187	0	ECON.6000	MGMT.6600	MKT.6800	24	0
MGMT.6650	MKT.6800	137	0	MGMT.6600	MGMT.6650	MKT.6800	24	0
ECON.6000	MGMT.6600	120	0	FIN.6710	INFS.6610	MGMT.6650	23	0
MGMT.6600	MGMT.6650	117	0	ECON.6000	FIN.6710	INFS.6610	21	0
ECON.6000	MKT.6800	116	1	ACTG.6920	MGMT.6600	MKT.6800	20	0
FIN.6710	INFS.6610	107	0	ACTG.6920	INFS.6610	MGMT.6650	17	1
ECON.6000	FIN.6710	102	0	ACTG.6920	MGMT.6650	MKT.6800	16	0
ECON.6000	MGMT.6650	101	0	ECON.6000	FIN.6710	MGMT.6600	16	1
FIN.6710	MGMT.6650	97	1	ECON.6000	INFS.6610	MKT.6800	16	1
FIN.6710	MGMT.6650	97	1	ECON.6000	MGMT.6650	MKT.6800	16	0
INFS.6610	MGMT.6650	97	0	FIN.6710	INFS.6610	MGMT.6600	16	0
ACTG.6920	MGMT.6650	91	0	ECON.6000	FIN.6710	MKT.6800	15	0
FIN.6710	MGMT.6600	90	1	FIN.6710	MGMT.6600	MGMT.6650	15	1
ECON.6000	INFS.6610	87	0	FIN.6710	MGMT.6600	MKT.6800	15	1
INFS.6610	MGMT.6600	82	0	INFS.6610	MGMT.6600	MKT.6800	15	0
ACTG.6920	MKT.6800	80	0	ACTG.6920	MGMT.6600	MGMT.6650	14	0
ACTG.6920	MGMT.6600	72	0	ACTG.6920	ECON.6000	MGMT.6650	13	0
FIN.6710	MKT.6800	70	0	ACTG.6920	ECON.6000	MKT.6800	13	1
INFS.6610	MKT.6800	70	1	ECON.6000	FIN.6710	MGMT.6650	11	1
BUAD.6980	FIN.6710	64	0	ECON.6000	FIN.6710	MGMT.6650	11	1
ACTG.6920	ECON.6000	60	0	ECON.6000	INFS.6610	MGMT.6600	11	0
BUAD.6980	MGMT.6650	60	0	ECON.6000	INFS.6610	MGMT.6650	11	0
ACTG.6920	INFS.6610	50	1	ECON.6000	MGMT.6600	MGMT.6650	11	0
ACTG.6910	ECON.6000	45	1	ACTG.6920	INFS.6610	MKT.6800	10	1
ACTG.6910	MGMT.6600	39	0	FIN.6710	MGMT.6650	MKT.6800	10	1
ACTG.6920	FIN.6710	39	0	FIN.6710	MGMT.6650	MKT.6800	10	1
BUAD.6980	MKT.6800	38	0	INFS.6610	MGMT.6650	MKT.6800	10	0
BUAD.6980	MGMT.6600	37	0	BUAD.6980	FIN.6710	MGMT.6650	9	1
ACTG.6910	MKT.6800	33	0	BUAD.6980	FIN.6710	MGMT.6650	9	1
BUAD.6980	ECON.6000	31	0	ACTG.6910	ECON.6000	MGMT.6600	8	1
BUAD.6980	INFS.6610	31	0	ACTG.6910	MGMT.6600	MKT.6800	8	0
MGMT.6650	QM.6770	26	1	ACTG.6920	ECON.6000	INFS.6610	8	0
BUAD.6980	QM.6770	23	0	ACTG.6920	ECON.6000	MGMT.6600	8	0
ACTG.6910	MGMT.6650	22	0	BUAD.6980	MGMT.6650	MKT.6800	8	0
ACTG.6910	INFS.6610	21	1	ACTG.6910	MGMT.6650	MKT.6800	7	0
INFS.6610	QM.6770	19	0	BUAD.6980	FIN.6710	INFS.6610	7	0
ACTG.6910	FIN.6710	18	0	BUAD.6980	INFS.6610	MGMT.6650	7	0
ACTG.6920	BUAD.6980	18	0	BUAD.6980	MGMT.6600	MGMT.6650	7	0
FIN.6710	QM.6770	17	0	FIN.6710	INFS.6610	MKT.6800	7	1
ECON.6000	QM.6770	16	0	ACTG.6910	INFS.6610	MGMT.6600	6	1
MGMT.6600	QM.6770	12	0	ACTG.6920	ECON.6000	FIN.6710	6	0
ACTG.6910	BUAD.6980	10	0	ACTG.6920	FIN.6710	MGMT.6600	6	1
ACTG.6910	QM.6770	9	0	ACTG.6920	FIN.6710	INFS.6610	6	0
MKT.6800	QM.6770	9	0	ACTG.6920	FIN.6710	MGMT.6650	6	1
ACTG.6920	QM.6770	6	0	ACTG.6920	FIN.6710	MGMT.6650	6	1
ACTG.6910	ACTG.6920	2	0	ACTG.6920	FIN.6710	MKT.6800	6	0

Notes: Frequency of course association from all students taking two or more courses in a semester. Where the value in the column titled “opt” equals 1, two of the courses are directly linked in Figure 3.

Table 8: Actual and optimal course sequences.

course	description	t-test	regression	composite	actual
ACTG.6910	Accounting and Business Decisions	8	9	8.5	1
MGMT.6600	Study of Organizations	7	8	10	2
MKT.6800	Marketing Management	9.5	4	8.5	3
ECON.6000	Managerial Economics	5	4	3	4
ACTG.6920	Financial Statement Analysis	6	7	7	5
INFS.6610	Information Systems Management and Applications	2	1	1.5	6
MGMT.6650	Operations Management	3.5	4	5	7
FIN.6710	Financial Analysis	3.5	4	5	8
QM.6770	Computer-Based Decision Modeling	1	4	1.5	9
BUAD.6980	Strategic Management	9.5	10	5	10

Notes: Ranks calculated from Equation 1. Actual based on the top matrix in Table 2.

Summary and Conclusion

The point of this exercise was to seek insight into the effect of course sequencing on student performance. We used two different methods—t-tests and fixed-effects OLS models—to identify course-pairs for which taking a prior course led to a significant improvement in student performance in a subsequent course. We constructed graphical representations of the results and produced a proposed course sequence based on those graphical representations. We also tried to provide some insight into the actual sequences in which courses have been taken.

Figure 3 and Table 8 summarize our findings. These show that some courses, both directly and indirectly, draw on student knowledge obtained in earlier courses, whereas other courses function primarily to provide that knowledge. Hence, they provide a basis for developing a course sequence. Courses such as INFS 6610 and QM 6770 clearly belong at the beginning, even though students have tended to take them in the latter half of the sequence. Courses that students often take first (and benefit from Economics and Finance), such as ACTG 6910, MGMT 6600, and MKT 6800, actually belong near the end. Surprisingly, the capstone course BUAD 6980 appears not to draw heavily on knowledge obtained in earlier courses. This may indicate insufficient integration of courses into a cumulative learning process.

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