APPENDIX (ONLINE SUPPLEMENT):

COMPLEMENTARITY EFFECTS OF R&D AND INFORMATION TECHNOLOGY: A CASE STUDY OF A BIO-PHARMACEUTICAL FIRM

The pharmaceutical industry is an example of a sector where new advances in IT have significantly changed the process of drug discovery and development. A recent study by McKinsey also reports that pharmaceutical companies, which use IT in clinical trials processes increased their overall productivity by improving the speed, quality and costs associated with these processes (Marwaha et al. 2007). Estimated savings from IT-driven initiatives that improve the overall efficiency of clinical trials is estimated to be in the range of $50 million to $100 million. Their study describes the role of IT in four areas of R&D related to drug discovery and development during clinical trials: improving resource allocation for integrated, enterprise-wide planning of clinical trials; better data management through electronic case report forms; enabling easier access to researchers though electronic data capture tools by providing standardized interfaces; and providing greater visibility across the clinical trials process by eliminating bottlenecks.

We conducted a detailed field study and interviewed key executives to understand the role that IT plays in the three phases of research and development involving new large molecule drugs at Alpha Laboratories, a California-based public bio-pharmaceutical company. Using a grounded case study, based on interviews with managers and senior executives, we describe the role of IT in managing their drug identification and development processes.

Due to the large investment needed for commercialization, Alpha allied in September 2002 with a larger, pharmaceutical company ("Mega") based in the mid-Western United States. This created the need for many years of close interactions between management professionals and scientists at both companies during the three R&D phases: discovery, development, and commercialization. Based on our observations as well as interviews with key R&D managers, we found that increasing intensity of the usage of IT greatly facilitated collaboration between companies,

especially increasing the frequency of communication while reducing the frequency of travel between the locations, situated thousands of miles apart. IT also helped Alpha simplify, standardize, and streamline its drug discovery and development processes. In the early discovery stage, the company kept close track of all the compounds screened and the results obtained from their tests. While this data used to be recorded in individual scientists' notebooks, they are now increasingly being captured in an enterprise software system available throughout the company as well as at its development partner. In addition, IT helped automated a number of enabling steps such as (a) lab supplies procurement, (b) screening of compounds, and (c) synchronization of team members from multiple functional disciplines.

IT has greatly altered the development phase of R&D, which involves multiple rounds of testing to establish the safety and efficacy of the drug developed. This phase starts with pre-clinical tests, done both in-vitro and in-vivo, that generates a lot of data. This is followed by clinical trials on humans in increasingly large numbers. As other observers have also noted (Marwaha et al. 2007; Mendelson 2007), IT plays an increasingly critical role in orchestrating the clinical trials processes using systems such as electronic case report forms and electronic data capture formats. While much more remains to be done to reduce the cost and time incurred in conducting clinical trials, efforts are afoot to significantly improve the data quality and efficiency of multiple rounds of drug testing.

Alpha launched two drugs to treat metabolic disorders (specifically diabetes) which received approval in the spring of 2005. The company uses IT to synchronize both its supply and demand chains. More recently, the company has also started working with drug distributors and retailers to automate the refilling process and ensure prescription compliance. Alpha also diligently collects and analyzed data on side-effects or issues from using these drugs. The data collected from the three phases is used by Alpha's senior management to make portfolio investment decisions. In addition, to improve its execution of business processes across the board, the company has implemented a metrics dashboard. To reduce the burden on collecting and tracking metrics, the company has rolled out software that automatically computes and communicates key metrics from the raw data input by the

scientists. These tools have helped the company overcome the initial resistance to implement a metrics-driven management approach from its scientists due to the increased effort required to track these metrics.

Alpha's scientific and business managers report that IT has greatly helped improve the company's efficiency, product pipeline visibility, and responsiveness to new market and technical information. A key challenge for the company's senior management is to broaden its product pipeline to target adjacent market opportunities. IT seems to have helped it initiate many more projects without having to add concomitant resources. Though there are still some challenges associated with the presence of IT silos across the different phases of R&D, senior executives at Alpha report that they could not have built revenues exceeding $500 million in 3 years without the crucial enabling role of IT.

This case study provides the impetus for studying the joint effect of R&D and IT using empirical evidence across a broad cross-section of industries. We argue that implementing an integrated IT platform can provide several potential benefits: (a) reduce bottlenecks in the availability of experimental subjects (patients) by providing greater visibility into the patient recruitment pipeline, (b) streamline workflows by providing automated notification, such as alerts in clinical trials management systems to provide warnings when data entry is delayed and/or trigger follow-up actions to reduce bottlenecks, and (c) provide standardized interfaces that can help firms analyze and compile clinical trials data received from a number of study partners. Such integrated use of IT within core operations, such as R&D, constitutes the next frontier in the assimilation of IT within major companies and provides a useful setting for our research on the complementarities of firm-level R&D and IT investments.

Table A1. Random Effects Estimation Results with AR(1) Errors: IT and R&D Scaled by Sales (N = 675)

	Predicted Sign	Model 1 Coeff. (z-stat.)	Model 2 Coeff. (z-stat.)	Model 3 Coeff. (z-stat.)
Intercept		-0.085	-0.564	-0.671
		(-0.15)	(-1.01)	(-1.20)
IT	+	0.216***	0.159**	0.128**
		(3.40)	(2.51)	(1.98)
R&D	+		0.409***	0.329***
			(5.00)	(3.73)
IT x R&D	+			0.124**
				(2.29)
ADVT		8.573**	8.849**	9.488***
		(2.38)	(2.54)	(2.73)
ASSET		0.432	0.842*	0.801*
		(0.88)	(1.74)	(1.66)
LOSS		-0.352***	-0.482***	-0.476***
		(-2.74)	(-3.70)	(-3.67)
SIZE		0.028	0.087	0.094
		(0.46)	(1.45)	(1.57)
Industry Q		0.831***	0.744***	0.760***
		(7.53)	(6.72)	(6.88)
Wald Chi^2 (df)		129.48 (14)	161.18 (15)	167.10 (16)
		(p<0.01)	(p<0.01)	(p<0.01)
R^2		24.81%	32.31%	32.33%

Notes:

1. Year indicators are included in each model but the coefficients are not reported.
2. Significance of p-values are reported as follows: * p<0.10; ** p<0.05; *** p<0.01 (two-sided tests). Z-statistics are reported in parentheses.

Table A2. Random Effects Estimation with AR(1) Errors:
High R&D- versus Low R&D-intensity Firms

		HIGH R&D (N=343)			LOW R&D (N=332)		
	Predicted Sign	**Model 1 Coeff. (z-stat.)**	**Model 2 Coeff. (z-stat.)**	**Model 3 Coeff. (z-stat.)**	**Model 1 Coeff. (z-stat.)**	**Model 2 Coeff. (z-stat.)**	**Model 3 Coeff. (z-stat.)**
Intercept		0.089	-0.847	-0.822	0.386	0.257	0.300
		(0.10)	(-1.04)	(-1.05)	(0.87)	(0.54)	(0.62)
IT	+	0.318***	0.185*	0.058	0.130**	0.132**	0.214
		(3.04)	(1.77)	(0.53)	(2.06)	(2.11)	(1.49)
R&D	+		0.591***	0.425***		-0.213	-0.193
			(5.00)	(3.34)		(-0.65)	(-0.58)
IT x R&D	+			0.192***			0.148
				(3.28)			(0.64)
ADVT		5.318	6.285	6.629	12.562***	12.757***	12.783***
		(1.01)	(1.31)	(1.46)	(5.26)	(5.44)	(5.45)
ASSET		0.638	1.084	1.031	0.221	0.202	0.193
		(0.73)	(1.31)	(1.29)	(0.71)	(0.65)	(0.62)
LOSS		-0.492**	-0.791***	-0.763***	-0.260***	-0.265***	-0.266***
		(-2.03)	(-3.24)	(-3.14)	(-3.33)	(-3.35)	(-3.37)
SIZE		-0.057	0.043	0.032	0.055	0.058	0.054
		(-0.63)	(0.50)	(0.39)	(1.18)	(1.25)	(1.16)
Industry_Q		1.136***	1.007***	1.099***	0.289***	0.292***	0.293***
		(6.25)	(5.71)	(6.32)	(3.68)	(3.70)	(3.70)
Wald Chi^2 (df)		92.33 (14) (p<0.01)	126.76 (15) (p<0.01)	146.76 (16) (p<0.01)	93.76 (14) (p<0.01)	95.92 (15) (p<0.01)	96.20 (16) (p<0.01)
R^2		29.46%	40.38%	44.44%	32.84%	33.70%	33.82%

Notes:

3. The sample is partitioned into high versus low R&D subsamples based on the industry median of R&D.
4. Year indicators are included in each model but the coefficients are not reported.
5. Significance of p-values are reported as follows: * p<0.10; ** p<0.05; *** p<0.01 (two-sided tests). Z-statistics are reported in parentheses.