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ABSTRACT

Information Technology Use and Productivity at the Individual Level*

We employ a unique data set on white-collar workers that combines direct observations of individual use of information technology as well as objective information on individual performance. The main hypothesis we examine is whether heavier users of IT are more productive, and if heavier users of IT are indeed more productive, how does this increase in productivity manifest itself? Our results suggest that, controlling for other factors, the size of an individual's internal email network is more highly correlated with revenues generated by that individual than age, experience or education. Further, the number of unique electronic contacts is more significant than the number of messages, external network size, and all other measures of email communication including declared time spent on email. Additionally, even after accounting for the individual's number of unique contacts within the firm, the social network measure of "betweenness" is also highly correlated with revenues. We attribute the strength of these results to the fine grain detail of the data on this form of task-based white collar work.

JEL Classification: J24, L86 and O14
Keywords: information technology, productivity and social networks

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1. Introduction

Evidence now suggests that information technology (IT) increases productivity at the level of the macroeconomy (Jorgenson, 2001). Using industry-level data, Siroh (2002) has shown that IT increases productivity, while Brynjolfsson & Hitt (1996) have shown that there are similar effects at the level of the firm. There are also several studies that show that IT improves productivity in particular industries; Ichniowski, Shaw & Prennushi (1997), for example, find that modern technology and participatory work practices correspond to higher output in the steel industry. Yet despite the importance of productivity to national competitiveness and living standards, there is little data linking information technology to individual productivity.[1] How might IT help people at the micro level? Harder still, how can one tie use of technology to white-collar output?

We have identified a setting in which white-collar work has measurable inputs and outputs at the individual level, as well as a simple production process and have compiled a unique data set that helps shed light on both questions. Our data is from a management recruiting firm, and include direct observations of individual use of information technology as well as objective information on individual performance. We developed unique instrumentation that allowed us to capture all computer mediated communication over the course of more than six months at the individual message level.

Our primary measure of information usage is email communication. Secondary data on information technology come from survey data on perceptions. The data include more than 80% of project related staff – partners, consultants, and researchers – at a management recruiting firm. Among many rich measures of email use, we have:

- the number of email messages sent and received,
- whether messages were sent from or received by people inside or outside the firm,

[1] There are, of course, those who are not convinced that IT increases productivity. See Gordon (2000) and the references cited within. See Brynjolfsson and Hitt (2000) for an excellent survey on information technology and organization transformation and Bresnahan and Greenstein (1997) for survey article on technological progress and the use of computers.

- the size of an individual's internal network in terms of unique email contacts inside the firm,
- the size of the individual's external network in terms of unique email contacts outside of the firm,
- the topological structure of information flows,
- the size of email messages sent and received,
- whether an email contains an attachment, and
- proxies for the amount of time spent processing email.

In addition to the wealth of data on use of information technology, which are inputs into the production process, we also have precise measures of individual productivity in the form of (i) billing revenues generated on specific contracts and (ii) the number of contract completions attributed to each person.

The main hypothesis we examine is whether heavier users of IT are more productive, and if heavier users of IT are indeed more productive, how does this increase in productivity manifest itself? Management recruiting is an ideal setting for the analysis, since "production" is an extensive process of search and deliberation in order to match "potential candidates" with "clients." Clearly, in this industry, information is critical; professional networks and efficient use of information technology could increase productivity (See Rangan 2000).

Our results suggest that controlling for job level and the number of projects that an individual was working on, an individual's internal network size is more highly correlated with revenues generated by that individual than the "number of messages," "external network size," and all other measures of email communication including declared time spent on email. Additionally, this factor explains more of the variation in individual (billing) revenues than "years of education," "gender," "age," and "years of experience" combined. The results are slightly less significant, but robust to using the number of completed contracts as a measure of productivity rather than revenues generated.

After accounting for the individual's number of unique contacts within the firm, the social network measure of "betweenness" – a normalized count of the number of times an individual appears on the shortest path between all agent pairs – is also highly correlated with revenues. That is, individual productivity is higher when the

social network measure of betweenness is higher. This suggests that individuals are more productive when positioned in heavier information flows. Our results provide empirical support for the proposition that individuals benefit from occupying an advantageous (social) position within a network position. Controlling for these two variables, information volume has little explanatory power.

The results that measures of contact network size and betweenness are statistically significant in explaining productivity are consistent with social network theories which predict that individuals in more central positions (Freeman 1979), or who can bridge information pools (Granovetter 1973, Burt 1992) will have better access to valuable information.

In addition to the (objective) email measures, we find that higher values of perceived skill in using internal database tools and a higher perceived benefit from face-to-face (FTF) contacts are correlated with higher productivity, but these effects are not statistically significant.[2]

2. Model and Data

We will employ a simple model

$Q_i = \alpha + \beta H_i + \gamma X_i + \delta Y_i + \varepsilon_i$, where

Q_i is Output ($, Completed Contracts), H_i includes job type variables (i.e., Partner, Consultant, etc.), X_i includes human capital variables (i.e., Education, Experience, etc.), Y_i includes information technology variables (Network size, Betweenness, Email Volume, etc.), and ε_i is white noise. Although we employ a linear model, as we discuss in section 3.3., our main results are robust to alternative functional forms.

[2] In an earlier version of the paper, Gandal, King, and Van Alstyne (2005), we also found that there is a misperception of information overload as well, that is, individuals who agreed with the statement that they suffer from information overload were no less productive than individuals who indicated that they did not suffer from information overload.

H_i and X_i are likely exogenous for the period of our data, but Y_i is composed of IT use variables like internal network size, betweenness, email volume, etc. The IT use variables are possibly endogenous in the model, since it may be the case that people who bring in more revenues are more popular. Since we do not have exogenous instruments for the IT use variables, we will only be able to examine the raw correlations in the data rather than causality. The main goal of our project is to determine which IT use variables are most highly correlated with productivity; hence we believe the OLS regressions are sufficient for our analysis. We are careful not to attach a causal interpretation to the results.

Data for this study come from three sources. Communications data represent direct observation of all email traffic on a corporate mail server from August 2002 to June 2003. Raw data were encrypted prior to disclosure to ensure privacy and each voluntary participant was paid $100 if he or she chose not to opt out of the study.[3] Figure 1 shows the observed communications network from a sub-period for which we have data. Nodes represent individual people; links represent messages between individuals while thicker lines designate more frequent communication. Individuals such as w26 have both a relatively high number of incoming contacts and also a relatively high index of "betweenness."

[3] See Van Alstyne, M. & Zhang, J. (2003) for the development of the tools to gather these data.

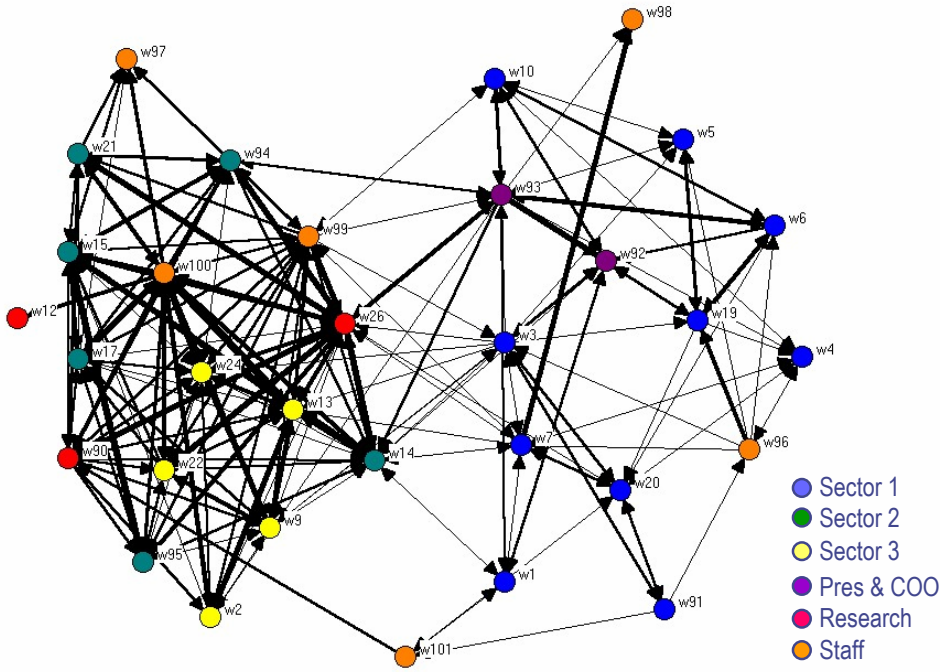

Figure 1 – The observed contact network over a six month period[4]

Perception data were gathered using a 52 question online survey. Participants were contacted by the chief technology officer, received $25 for completed surveys, and offered a chance to view their responses ranked against those of average respondents upon conclusion of the study. Voluntary participation in both activities (the email activity and the survey) exceeded 80%.[5]

Professionals at management recruiting firms bring in both "booking" and "billing" revenues, where booking revenues are the fees earned from bringing the work into the firm, while billing revenues are earned by fulfilling the contract. We have data on individual billing revenues and completed contracts from 2002 (the full year) and 2003 (the first half of the year).[6] The regressions with 2002 revenues as the

[4] In order to preserve firm confidentiality, we cannot reveal the three sectors, but they include some of the following industries: consumer products, real estate, health care, the computer industry, and education. Estimated coefficients on dummy variables for these sectors are insignificant in the regressions below; hence given the limited number of observations, we do not include them in the analysis.

[5] The differences between participants and non-participants in terms of billing revenues and completed contracts are not statistically significant.

[6] Revenue from completed projects is divided among participants of a completed contract based on established formulas that depend on magnitude and type of the contribution, as well as rank.

dependent variable fit the data much better than regressions using 2003 revenues as the dependent variable.[7,8]

Since we employ billing revenue, an important question is how people end up working on particular projects. Our discussions with executives in the management recruiting firm suggest that work typically is brought into the firm in two ways. In the first case, the firm gets a request for a competitive proposal. In this case, contacts with the prospective client are handled by a group leader for the area (e.g. education, health care, etc.) who assembles a team to make the proposal. In the second case, an individual brings in the business directly through his/her contacts.[9]

In the first case, the team assembled to generate the business typically continues to work together to execute the contract. Here assignment to projects is via an "internal market system." In the second case, the "rainmaker" typically makes the decision regarding who's on the team. Since the "rainmaker" hopes to generate repeat business, it's likely that he/she will assemble the best team possible, that is, assignments are also likely made via the internal market system. Hence in both cases, billing revenues are typically performance based and are likely an appropriate measure of productivity.

2.1 Variables employed in the study

Summary statistics appear in Table A1 in the Appendix. For clarity in notation, we use the following conventions in defining our variables: "internal" and "external" refer respectively to contacts located inside or outside the firm, "in" and "out" refer respectively to the direction of the communication where "in" means receiving and "out" means sending; "net" refers to the number of unique network contacts, and "vol" refers to message volume.

REVENUES - Revenues in $ billed by the individual for completed contracts in 2002.

[7] The correlation between revenues from 2002 and completed contracts completed is very high (0.89), while the correlation between completed contracts and revenues from 2003 is relatively low (0.25).
[8] Pursuant to our contract on the use of human subjects, no data on individual identities are available as a result of this study.
[9] The norms for two cases depend on the industry. In health care, repeat business accounts for 90%, so the second case applies here. In education, repeat business counts for "only" about 60% of the work; hence the first case would apply more often here.

SALARY – 2002 salary in $.

COMPLETED CONTRACTS – number of contracts that were completed during the August 2002-June 2003 period. Full time equivalents are based on the share of revenues attributed to an individual.

EDUCATION - Years of education.

EXPERIENCE - Years of experience in the industry.

GENDER - A dummy variable that takes on the value 1 if the individual is male and zero if female.

AGE – Age of the Individual.

PARTNER - A dummy variable that takes on the value 1 if the individual is a partner and zero otherwise.

CONSULTANT - A dummy variable that takes on the value 1 if the individual is a consultant and zero otherwise.[10]

INTERNAL (EXTERNAL) IN-NET - Size of the individual's internal (external) contact network as measured by the number of unique individuals within the firm (from the outside) who *sent email to* the relevant individual. This includes cc messages.

INTERNAL (EXTERNAL) OUT-NET - Size of the individual's internal (external) contact network as measured by the number of unique individuals within the firm (from the outside) who *received email from* the relevant individual. This includes cc messages.

INTERNAL (EXTERNAL) IN-VOL – Daily average volume of incoming mail from contacts inside (outside) the firm.

INTERNAL (EXTERNAL) OUT-VOL – Daily average volume of outgoing mail to contacts inside (outside) the firm.

INTERNAL (EXTERNAL) IN-MSG-SIZE – Daily average size (in bytes) of messages from contacts inside (outside) the firm.

INTERNAL (EXTERNAL) EMAILS WITH ATTACHMENT – Daily average number of messages with an attachment received by an individual.

BETWEENNESS – A normalized count of the number of times an individual appears on the shortest path between all agent pairs including staff. A link between two agents exists if they exchanged 30 or more messages over six months. (There is very little difference in results if we use 10, 20, 30, 40, or 50 messages as a link.)

[10] All other individuals in the study are "researchers."

PROJECTS – The total number of projects that an individual is working on, averaged over two week intervals, and weighed by the fraction of reported effort on that project.

SEARCH TOOLS – A variable that that takes on a value of 0 to 500, where the individual is asked to agree or disagree with the following statement: "I am highly effective at using our in-house proprietary search tools. This means I know what information they contain and I can easily find, add and modify the records I need." A higher value of the variable means more agreement with the statement.

PFTF VALUE – The perceived value from face to face contacts. This value can range between 0 and 100, but perceived value on all measures of communication (face-to-face, telephone, email, instant messenger, computer display and hardcopy) was scaled to total 100.[11]

PTEL VALUE – The perceived value from using the telephone.

PEMAIL VALUE - The perceived value from using email.

PFTF TIME – The declared percent of time spent on face to face contacts. This value can range between 0 and 100. Further, the percent of time spent on all measures of communication (face-to-face, telephone, email, instant messenger, computer display and hardcopy) was required to total 100.[12]

PTEL TIME – The declared percent of time spent on the telephone.

PEMAIL TIME - The declared percent of time spent on email.

3. Empirical Results

We first ran a "benchmark" regression that included typical economic labor variables in productivity studies such as gender, age, education, and years of experience. We also included dummy variables for whether the individual was a partner or a consultant.

The regression in table 1 shows that only PARTNER and CONSULTANT are statistically significant in explaining the variation in revenue. These individuals bring in more revenue, other things being equal, because they are typically the ones that

[11] The average perceived value from the sum of telephone, face-to-face, and email communication exceeds 90% leaving only 10% for hardcopy, instant messaging, and "other" communications. Hence we focus on these three rather than looking at all six measures.

[12] The average perceived percent of time spent on telephone, face-to-face, and email communication exceeds 85% leaving only 15% for hardcopy, instant messaging, and "other" communications. Hence we focus on these three rather than looking at all six measures.

bring the projects into the firm. All of the other variables are insignificant and the explanatory power of the regression is quite low. The adjusted R-squared value is only 0.06. A regression that only includes dummy variables for PARTNER and CONSULTANT had an adjusted R-squared value of 0.05. Hence, the typical "labor variables" (GENDER, AGE, EDUCATION, EXPERIENCE) explain a very small amount of the variation in individual (billing) revenues.

	Dependent Variable: REVENUE	
Independent Variables	Coefficient	T-statistic
CONSTANT	232,917.4	0.47
GENDER	-33,699.0	-0.61
AGE	-4,786.2	-1.24
EDUCATION	-13,910.3	-0.61
EXPERIENCE	-3,244.8	-0.79
PARTNER	271,795.8	1.80
CONSULTANT	264,978.5	2.21
N of observations	32	
Adjusted R-squared	0.06	

Table 1: Benchmark Regression

The first regression of table 2 contains our "first" preferred model. Two IT variables, INTERNAL IN-NET and BETWEENNESS, are included in addition to PARTNER and CONSULTANT, as well as the number of projects on which an individual is working on. Both add significant explanatory power to the regression. The adjusted R-squared is 0.68, while the R-squared itself is 0.73. (The correlations among the variables in this regression appear in Table A2 in the appendix.)

Hence, even after controlling for an individual's number of unique average contacts (INTERNAL IN-NET), the BETWEENNESS measure is also significant (t=2.40 in the first regression in Table 2.) The results suggest that individual productivity is higher when the social network measure of betweenness is larger, that is when more information flows through that person. Being better positioned in the network also matters because it affects information flow among people. It is interesting to note that the measure of BETWEENNESS that provides the best fit includes everyone in the firm. BETWEENNESS measures that include researchers, partners, and consultants

but omit support staff do not explain productivity as well those that include all people in the firm.[13]

The second regression in table 2 shows an alternative preferred model that includes variables measuring the perceived benefit of other means of communication and skills (PFTFVALUE, PTELVALUE, and SEARCH TOOLS). We include these variables because we have no objective measures of the benefits from the use of the telephone, face-to-face contacts, or the ability to use the internal database. Our main results, that individual productivity is higher when an individual has a larger number of unique internal contacts and when his/her BETWEENNESS measure is higher, are robust to whether the perception variables are included or excluded.[14]

The third regression in table 2 shows that the four typical labor variables add virtually no explanatory power when added to the preferred regression in column one of the table. Indeed the adjusted R-squared falls from 0.68 to 0.65 when these four variables are added. The R-squared itself only rises from 0.73 to 0.75 with the inclusion of these four variables. The regressions in table 2 show that the factors associated with information technology have much more explanatory power than gender, age, education, and years of experience *combined*. For this reason, and because we have a limited number of observations, we do not include these variables in further analysis.

[13] Not surprisingly, the coefficient on PROJECTS is positive and significant as well. That is, controlling for IT use, those working on more projects have higher revenues.

[14] If we include relative time spent rather than perceived FTF or Telephone value, these two variables are completely insignificant and the other estimates remain virtually unchanged.

	Regression 1: Preferred Model		Regression 2: Preferred Model With Perception Variables		Regression 3: With Traditional Variables	
Independent Variables	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
CONSTANT	-355,896.3	-2.49	-527,067.2	-3.18	-291,308.6	-0.95
INTERNAL IN-NET	6,024.4	3.39	7,925.1	4.45	6,505.9	2.83
BETWEENNESS	104.8.5	2.40	77.5	1.79	85.5	1.57
PROJECTS	28,316.7	4.12	23,636.1	3.51	26,377.8	3.34
PARTNER	148,431.1	2.40	183,064.8	2.79	236,096.5	2.34
CONSULTANT	277,978.3	4.31	333,460.6	4.83	334,201.1	4.11
SEARCH TOOLS			168.79	1.13		
PFTF VALUE			890.31	0.93		
PTEL VALUE			1542.91	0.125		
GENDER					-36,608.2	-0.96
AGE					-1586.3	-0.64
EDUCATION					-1744.3	-0.11
EXPERIENCE					-1270.5	-0.44
N of observations	33		32		33	
R-squared	0.73		0.80		0.75	
Adjusted R-squared	0.68		0.73		0.65	

Table 2: Regression Results: Dependent Variable: REVENUES[15]

3.1 Alternative measures of email use: The importance of the internal network

A fairly striking but perhaps intuitive result is that what matters for productivity is how email is used. Regressions with another information technology measure as an explanatory variable instead of INTERNAL IN-NET yield weaker statistical significance than when INTERNAL IN-NET is included in the regression. These results are summarized in Table 3 and discussed below. Alternative information technology measures include contact location (inside versus outside the firm), volume (messages versus network size), and directionality (sending versus receiving). Table 3 shows the results of replacing INTERNAL IN-NET from the first regression in table 2 with alternative explanatory variables. These alternatives show weaker (if any) statistical significance and the predictive power of the regression falls. [16]

[15] We are missing one data point for the following variables: EDUCATION, EXPERIENCE, GENDER and AGE

[16] We obtain qualitatively similar results if we use the second regression in table 2.

Variable included in first preferred regression	*T-Statistic*	*Adj R^2*
INTERNAL IN-NET	4.45	0.68
Internal In-Net excluded and replaced by	*T-Statistic*	*Adj R^2*
INTERNAL OUT-NET	2.34	0.62
EXTERNAL IN-NET	-1.35	0.57
EXTERNAL OUT-NET	-0.20	0.55
INTERNAL IN-VOL	2.46	0.62
INTERNAL OUT-VOL	0.91	0.55
EXTERNAL IN-VOL	-0.80	0.55
EXTERNAL OUT-VOL	0.45	0.54
INTERNAL IN-MSG-SIZE	-0.62	0.55
EXTERNAL IN-MSG-SIZE	0.28	0.54
INTERNAL EMAILS WITH ATTACHMENT	1.45	0.57
PEMAIL TIME	-0.42	0.54
NO OTHER VARIABLE INCLUDED		0.57

Table 3 – Using alternative explanatory variables instead of INTERNAL IN-NET

We now briefly discuss some of the results in table 3. Is productivity more highly correlated with sending or receiving email? We find evidence favoring the latter variable. When we replace INTERNAL IN-NET with INTERNAL OUT-NET, we find that the internal outgoing network is significant in explaining productivity (t=2.34) but the predictive power of the model falls (to an adjusted R-squared of 0.62 from 0.68). Perhaps more importantly, when we include both variables in the regression, INTERNAL IN-NET is significant in explaining productivity (t=2.24), while INTERNAL OUT-NET is not significant (t=0.43).[17] This suggests that the information flowing to the individual is more important for his/her productivity than the information flowing from the individual.

A variant on the directionality issue is to explore the *volume* of email sent and received and whether this is inside or outside the firm. Higher internal volumes, for example, might be consistent with task delegation. Substituting INTERNAL IN-VOL for INTERNAL IN-NET, the estimated coefficient is positive and statistically significant in explaining productivity (t=2.46), but the predictive power of the regression falls; the adjusted R-squared is 0.62. Further, when we include both INTERNAL IN-NET and the INTERNAL IN-VOL in the regression, INTERNAL

[17] The regressions with INTERNAL IN_NET and the other variables are not shown in Table 3. They are available on request.

IN-NET is significant in explaining productivity (t=2.13), while the INTERNAL OUT-VOL is not significant (t=0.47). This suggests that internal network size is more important than the volume of email.

Substituting INTERNAL OUT-VOL for INTERNAL IN-NET, the estimated coefficient is positive, but insignificant (t=0.91) and the predictive power of the regression falls significantly. (The adjusted R-squared is 0.55.) Including both INTERNAL IN-NET and the INTERNAL OUT-VOL in the regression, INTERNAL IN-NET is significant in explaining productivity (t=3.17), while the INTERNAL OUT-VOL is not significant (t=-0.26). Again this suggests that the information flowing to the individual is more important for his/her productivity than the information flowing from the individual.

Another possibility is that the volume of external information received matters. This might loosely be interpreted as having more frequent or updated information. To explore this possibility, substituting EXTERNAL IN-VOL leads to an insignificant relationship with productivity (t=-0.80) and the predictive power falls; the adjusted R-squared is 0.55. Similarly table 3 shows that external network size (EXTERNAL IN-NET and EXTERNAL OUT-NET) are insignificant in explaining productivity. This suggests that internal network size matters more than the volume of external information flowing in to individuals in the firm. This is again consistent with hypothesis the benefits from occupying an advantageous position in the network structure.

If instead of volume, we substitute message size, there is no meaningful relationship with output regardless of whether this is internal incoming size (t=-0.62) or external incoming size (t=0.28). We also examined message the effect of included attachments. This might represent information either in template form or in alternative presentation formats. If we replace INTERNAL IN-NET with the "number of email messages with an attachment," this variable has a positive but insignificant effect on productivity (t=1.45), and the adjusted R-squared is lower than the regression with INTERNAL IN-NET. When we put both of those variables in the regression, INTERNAL IN-NET is significant in explaining productivity (t=3.09), while the "number of internal email messages received with an attachment," is not

significant (t=0.93). That is the internal network size matters more than message size or whether the email has an attachment.

Finally, when we replaced INTERNAL IN-NET with the declared percent time spent on email (PEMAIL TIME), the latter was insignificant in explaining productivity; (t= -0.42). When we put both of those variables in the regression, INTERNAL IN-NET is significant in explaining productivity (t=3.45), while the (declared) percent of time spent on email is not significant (t=-0.89). If anything, controlling for the internal network size, declared time spent on email detracts from productivity.

In summary, incoming messages matter more for productivity than outgoing messages. The message size or whether it has an attachment is not important for productivity. Sending or receiving a large message volume is much less important for productivity than the size of the internal contact network within the firm.

3.2 The effect of perceptions on productivity

When we add three perception variables to the first regression in table 2 (perceived skill with SEARCHTOOLS,[18] perceived value of face to face contacts, and perceived value of telephone use), we obtain the second "preferred" regression in Table 2. The adjusted R-squared increases to 0.73 relative to the model without the perception variables. The second regression Table 2 shows that the effect of perceived skill with SEARCHTOOLS on productivity is positive, but not significant (t=1.13). The regression also shows that high value placed on face-to-face (FTF) interactions lead to improved productivity, but the effect is also not significant (t=0.93).[19]

When we exclude INTERNAL IN-NET, BETWEENNESS, but include all three perception values discussed above, as well as the perceived value of email use and PROJECTS, we find that the coefficients associated with PFTF VALUE and PEMAIL VALUE are both positive and statistically significant at the 10% level

[18] One could argue that SEARCHTOOLS should be included in the first regression because it is perception of skill rather than value. Our results are robust to this change.

[19] The theoretical literature (Seeley 2001) suggests that FTF contact is a good starter for a relationship but that email can then sustain it. (Email doesn't sustain as well if it's used as a starter.) If we eliminate perceived value from telephone use from the second regression in table 2, the coefficient on PFTF VALUE is positive and statistically significant. We don't have sequencing here but this result would be consistent with the theoretical literature on this issue.

(t=1.76 and t=1.70 respectively), while the estimated coefficient on PTEL VALUE is positive, but not statistically significant (t=0.68). The adjusted R-squared of the regression is only 0.38.

3.3 Robustness to functional form and alternative dependent variables

In terms of model specification, we find that the linear model performs better than models with different functional forms. The results are qualitatively similar with the exception that BETWEENNESS is no longer statistically significant. In particular, taking the natural logarithm of all of the quantitative variables, the adjusted R-squared of the "log/log" model using the first regression in table 2 is slightly lower than that of the linear model (0.66 vs. 0.68) and BETWEENNESS is no longer statistically significant (t=1.03) (See table 4.) A similar result obtains when employing the log/log model using the second regression in table 2. The adjusted R-squared is lower than that of the linear model (0.73 vs. 0.70). Again, the main results are again qualitatively similar, but BETWEENNESS is not statistically significant (t=0.33).

In the case of a "log/linear" model, i.e., taking the natural logarithm of the dependent variable, but using the explanatory variables in levels, we find that the adjusted R-squared of the log/linear model using the first regression in table 2 is lower than that of the linear model (0.68 vs. 0.61). In this case, BETWEENNESS is again statistically significant. Hence the results are qualitatively similar to the linear model (See table 4). When employing the log/linear model using the second regression in table 2, the adjusted R-squared is lower than that of the linear model (0.73 vs. 0.64). The results are again qualitatively similar, with the exception that BETWEENESS is no longer statistically significant (t=1.15).

	Regression 1: log/log model Dept. Variable L_REVENUES			Regression 1: log/linear model Dept. Variable L_REVENUES	
Indep. Variables	Coefficient	T-stat	Indep Variables	Coefficient	T-stat
CONSTANT	8.05	6.94	CONSTANT	11.06	29.22
L_INTERNAL IN-NET	0.89	3.18	INTERNAL IN-NET	.014	3.08
L_BETWEENNESS	0.021	1.03	BETWEENNESS	.00021	1.80
L_PROJECTS	0.39	5.06	PROJECTS	.071	3.87
PARTNER	0.37	2.46	PARTNER	0.35	2.13
CONSULTANT	0.62	3.97	CONSULTANT	0.62	3.64
N of observations	33			33	
R-squared	0.72			0.67	
Adjusted R-squared	0.66			0.61	

Table 4: Regressions Using Alternative Functional Forms[20]

We then examine the results using an alternative dependent variable. We find that most of the variables in the two preferred regressions in table 2 are statistically significant when we use COMPLETED CONTRACTS as the measure of productivity instead of REVENUES. The predictive power of the regressions in Table 4 is lower, however, than those in table 2; the first model in Table 5 has an adjusted R-squared of 0.55 (vs. 0.68 for the corresponding model in table 2).

When we add the perception values, Table 5 shows that a similar pattern emerges. In this case all of the variables in the preferred regression are statistically significant in explaining productivity and SEARCHTOOLS become more significant as well. The other perception variables have the same signs as in Table 2 and are again statistically insignificant.[21]

[20] A variable with an "L_" in front of it is the natural log. For example, L_INTERNAL IN-NET is the natural log of L_INTERNAL IN-NET.

[21] When we add the traditional labor variables (gender, age, experience and education) to the first regression in table 4, all are statistically insignificant.

	Preferred Regression Without Perception Variables		Preferred Regression With Perception Variables	
Independent Variables	Coefficient	T-stat	Coefficient	T-stat
CONSTANT	-2.71	-0.98	-7.56	-2.35
INTERNAL IN-NET	0.042	1.21	0.79	2.29
BETWEENNESS	0.0021	2.46	0.0016	1.95
PARTNER	1.86	1.55	2.49	1.96
CONSULTANT	4.03	3.23	4.80	3.59
PROJECTS	0.49	3.64	0.37	2.80
SEARCH TOOLS			0.0059	2.05
PFTF VALUE			0.022	1.20
PTEL VALUE			-0087	-0.37
N of observations	32		32	
R-squared	0.62		0.71	
Adjusted R-squared	0.55		0.62	

Table 5: Completed Contracts as a Measure of Productivity

Finally, the importance of having productivity variables (REVENUES and COMPLETED CONTRACTS) rather than salary can be illustrated by running the preferred regressions with SALARY as the dependent variable. In regressions identical to those in Table 2 with SALARY as the dependent variable, the estimated coefficient on INTERNAL IN-NET is positive although not quite statistically significant, while the estimated coefficient on BETWEENNESS is completely insignificant in explaining salary.

5. Conclusions and Further Discussion

Using data on management recruiting, we find evidence that, controlling for the number of projects, individual productivity is higher when an individual has a larger number of unique internal contacts and when his/her BETWEENNESS measure is higher. These factors show a more statistically significant association with output than age, experience, gender, and education controlling for factors such as project load and job level. These findings are based on a unique data set that affords precise and objective measures of individual performance, information flows, and contact networks.

Our results are consistent with social network theories that argue for the advantages of having a large contact network and being in the center of the flow of information. Substituting competing metrics such as inbound messages, outbound messages, and outbound contacts weaken the significance but leave intact the principal conclusion that heavier use of IT for communication exhibits increased productivity. Despite the fact that management recruiting firms disseminate information to external sources, there is no evidence in our data that productivity differences (at the individual level) are explained either by external volume or external contacts.

Although this is a single study, results based on management recruiting data may be representative of a variety of white-collar work. Professions with similar case-based or project work include sales, accounting, fund raising, law, medicine, real estate, and consulting. All of these activities involve an extensive process of search and deliberation in order to match "potential candidates" with "clients." In such cases, professional networks can prove useful (Rangan 2000). Thus while the magnitudes of specific coefficients are likely to be industry specific, the general results regarding the IT factors that explain productivity may be more general.

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Appendix

Variable	Mean	Standard Dev.	Minimum	Maximum
REVENUES	435,695	140,119	211,353	773,280
SALARY	249,028	117,489	70,783	510,027
GENDER	0.58	0.50	0	1
AGE	47.09	9.06	28	64
EDUCATION	17.78	1.36	16	21
EXPERIENCE	15.91	9.14	3	39
PARTNER	0.45	0.51	0	1
CONSULTANT	0.48	0.51	0	1
INTERNAL IN-NET	69.15	10.04	43	87
INTERNAL OUT-NET	47.67	15.26	13	83
EXTERNAL IN-NET	879.03	709.71	131	2483
EXTERNAL OUT-NET	297.61	295.07	35	1439
INTERNAL IN-VOL	7.08	2.68	3.21	12.03
INTERNAL OUT-VOL	4.51	2.52	0.69	10.82
EXTERNAL IN-VOL	15.54	10.17	3.61	47.3
EXTERNAL OUT-VOL	4.91	3.50	0.4	15.07
INTERNAL IN SIZE	37.02	13.36	11.5	75.89
EXTERNAL IN SIZE	33.95	12.93	15.58	62.08
INTERNAL IN ATTACH	4.29	1.57	1.4	8
BETWEENNESS	378.32	364.43	0	1625.72
SEARCH TOOLS	318.58	98.66	86	467
PROJECTS	4.70	2.13	1.5	10.22
COM CONTRACTS	6.04	2.29	1.15	10.38
PFTF VALUE	33.96	19.48	0	80
PTEL VALUE	35.37	15.08	10	70
PEMAIL VALUE	20.81	11.51	0	50
PFTF TIME	19.61	15.80	0	75
PTEL TIME	43.61	16.81	10	70
PEMAIL TIME	22.88	11.97	5	50

Table A1 Descriptive Statistics[22]

[22] N=33 for all variables except EDUCATION, GENDER, AGE, and EXPERIENCE (N=32).

	Revenues	Internal In-Net	Betweenness	Partner	Consultant	Projects
Revenues	1.00					
Internal In-Net	0.43	1.00				
Betweenness	0.43	0.46	1.00			
Partner	-0.20	0.21	0.11	1.00		
Consultant	0.30	-0.36	-0.16	-0.89	1.00	
Projects	0.54	0.28	0.13	0.07	-0.09	1.00

Table A2: Correlation among Variables in Preferred Regression