

Information Worker Productivity: Evidence from Worker Output, Compensation and Email Traffic Data

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Introduction

Information workers now account for as much as 70% of the U.S. labor force. The real output of most information workers is difficult to measure. Counting the number of meetings attended or the number of memos filed is not closely linked to the value they may, or may not, create. Yet if IT is to have a significant effect on the economy, it almost surely must be via its use by information workers and the tasks they perform. Does the use of IT lead professionals to complete their tasks more quickly? Does it allow a given worker to do more tasks at a given time? Can information work be explicitly linked to revenues?

In this study we focus on executive recruiters, a.k.a. head hunters, whose primary work involves filling specific job openings. Because the projects completed by each recruiter, and the corresponding revenue impact, are explicitly measured in the firms' accounting statements, the problem of measuring output can be largely addressed in this setting. Output variables for this study include individual worker level revenues, worker compensation, project completion rates, and project duration. IT variables focus on the use of the technology, not merely its presence, and include direct, message-level observation of communications volume, the size and shape of email contact networks, professed ability to use database technology, and relative time spent on various tasks. When combined with interviews and visits, these data enabled us to specify and estimate several equations relating technology, skill, worker characteristics, task completion, revenue and compensation.

Although our analysis is preliminary, our findings suggest that using IT has a statistically significant correlation with individual information worker

productivity (as measured via increased revenues), completed projects, and individual compensation. Workers who use IT to manage larger social networks perform better on average, as do those who have ability to use IT to manage data.

By what mechanism does the use of IT affect performance? A natural presumption is that computers speed up information work. Certainly, even the simplest computer can calculate millions of times more quickly than humans. Interestingly, however, we did not find that heavy IT users completed projects any more quickly than their peers. Instead, we found that heavy IT users worked on more projects simultaneously and thus completed more projects, and earned more revenue, per period, even while taking slightly *longer* on average for individual projects. Finally, our data enabled us to model and measure the way effort on various tasks, as well as project completion and revenue generation, affected individual worker compensation. Arguably, this is the production function that employees care about most. Consistent with multitask principal-agent theory, we found that compensation was tightly linked to observable output and that more observable tasks were more highly correlated with compensation. Specifically, the more highly visible task of interacting and managing people as opposed to data is also associated with a disproportionately high benefit in terms of compensation.

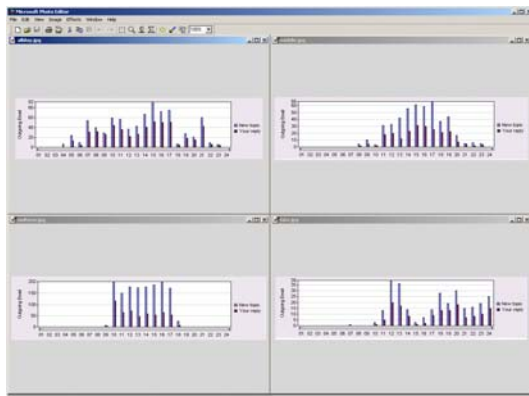
Using these data, we are able to better understand some of the internal workings of a group of firms which rely heavily on information work and information workers. We can measure some of the correlations among key variables of interest and thereby understand not only the ways that IT affects intermediate and final output, but also the compensation and incentive systems that are at work. However, this approach also has its weaknesses. In particular, since we have data on such a small fraction of the economy, our findings may not be completely generalizable. The results should be interpreted as descriptive of the firms, workers, technologies and practices in our sample, but are not necessarily valid outside our sample.

Research Data

Almost all information workers use IT intensively. However, their productivity is notoriously difficult to measure. As a result, there is virtually no quantitative research on information worker productivity, to date.

To address the unusual difficulty in measuring information worker productivity, we focus on a uniquely measurable type of information work: projects in the recruiting or executive search industry. Projects involve a well-defined contract for locating and vetting high quality executives on behalf of a client. Information flows and access also affect project success rates. Data for this study include three data subsets.

1. Exact internal accounting records of: revenues generated by individual recruiters (1999-2003); project start and stop dates; projects handled simultaneously; labor costs and compensation; project team composition; cancelled projects; and job level of placed candidates
2. Nine months of complete email history captured from the corporate mail server using specially developed capture software specific to this project. Spam messages were excluded by focusing on internal communications or external contacts who had received at least one message from anyone inside the firm.¹
3. Collected answers to surveys of information seeking behaviors, perceptions, experience, education, and human factors.



¹ A joint F test comparing performance means of those who opted out with those who remained did not show statistically significant differences. F (Sig): Rev02 2.295 (.136), Comp02 .837 (.365), Multi .386 (.538).

Figure 1: Daily send and reply volumes of four individuals allow fairly precise estimates of communications patterns and labor hours.

Together, these data provide a desktop level view of how different professional workers use IT in conjunction with measures of individual performance. The sum of individually secured contracts also provides a complete picture of firm-level revenues. In addition, we have direct observation of a stream of communications behaviors.

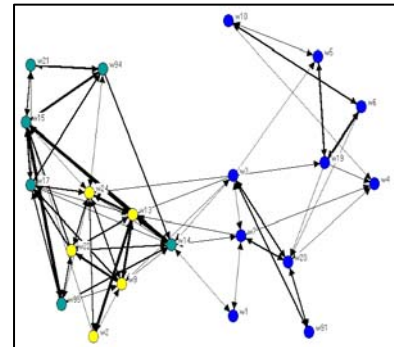


Figure 2: Communications volumes shown for one week are represented as heavier lines among workers in three different industry sectors. A geographic divide also separates two offices. It shows that although all workers are technically connected by email, actual communications cluster by geography and industry sector.

Models and Hypotheses

These data afford the opportunity to construct two distinct models of activity representing a production sequence within the firm. The first is a job task model in which agents take on projects, literally a contract, to locate a candidate for a specific client. The number and duration of these jobs then determine total dollar “billings.” These represent firm revenues and typically equal one-third of a placed candidate’s final salary. Taken independently, this fragment represents the white collar production function. Given revenues, the second model captures the principal-agent relationship between the recruiter and the firm.

A model for production activity can be specified as in equation (1). This specification resembles that of Ichniowski, Shaw & Prennushi, 1997².

$$(1) \quad Q_i = \alpha + \beta H_i + \gamma X_i + \delta Y_i + \varepsilon_i$$

² Ichniowski, C., K. Shaw, and Prennushi (1997). “The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines.” *American Economic Review* 87(3): 291-313

Also, increments to R^2 , PE and Box-Cox tests indicate this additive form is preferred to a multiplicative Cobb-Douglas specification.

The determinants of productivity (Q_i) in eq. (1) include dummy variables (H_i) for the industry sectors (eg. finance, health care) and percentages for the job level of searches (eg. CEO, VP, other), human capital (X_i) reflected in recruiter's years of experience, information behavioral treatments (Y_i), constant (α) and error terms. Years of education was originally included as a control in X_i , but was dropped after it was found to have little effect. Capital is included in the constant term since it is the same for all recruiters. Dummy variables that were found to be statistically significant in any of the regressions were kept and used in all regressions while the others were discarded to preserve degrees of freedom.

A Multi-tasking Project Model

If we consider white collar workers as managers of queued tasks, each with distinct start and stop points, we may be able to measure the relationship of IT and non-IT factors to intermediate measures of output. Data on project loads start times, and stop times over the sample period index the rate at which projects are completed.

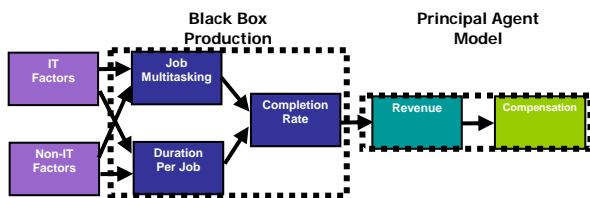


Figure 4 – This schematic elaborates the production function as a set of queued job tasks. Influence of IT and non-IT input factors can then be examined at the task level.

An equation representing the relationship of completed projects to simultaneous projects and throughput can be specified in a simple queuing model as follows:

$$(2) \quad n_i = a \cdot m_i \cdot \lambda_i \cdot e_i$$

Taking logs provides the linear expression $\ln(n_i) = \alpha + \ln(m_i) + \ln(\lambda_i) + \mu_i$ where n_i represents the number of completed projects, m_i gives the number of multitasked projects, and λ_i is throughput or $1/\text{AverageDuration}$. Terms α and μ_i are the constant and error terms respectively.

A Multi-task Incentive Model

For the incentive stage, consider a multi-task model in the spirit of Holmstrom-Milgrom (1991)³ and Hu, (2004)⁴. There are two tasks that agents (partners, consultants, and research staff) might perform to generate revenue. One IT – related task (“data manipulation”) is studying and managing data in the database, modifying stale records, and generating search reports. Another IT – related task (“networking”) is communicating with potential clients and recruits. The firm can also easily observe total revenues brought in from each client. In particular, the firm can observe and reward the addition of new clients.

Data manipulation increases a firm’s revenue, but the effect is indirect. Many activities performed at a computer may not be productive. Indeed, our analysis found that self-reported time spent on public web access pages appears to be weakly unproductive. Thus, we consider the direct effort of data entry to be less observable though not unimportant. On the other hand, networking increases the number and strength of an agent’s contacts. New clients and placements by an agent are, in fact, recorded and thus effort on networking can be more easily measured. Let the low and high observability tasks be T_L – “data manipulation” and T_H – “networking.” Empirically, we are able to observe T_H directly as email contact networks of recruiters and T_L as their self-reported ability to locate and modify database records.

The detailed employee level data we have collected provides an ideal testing ground for this implementation of our proposed production function and implementation of multi-task incentive theory. In particular, our analysis leads to the following testable predictions:

- H1: Revenues earned by recruiters depend positively on their project completion rate.
- H2: Project completion rate is i) a decreasing function of the average time per project (duration) and ii) an increasing function of the average number of projects processed at a time (multitasking).

³ Holmstrom, B and P. Milgrom (1990) “Regulating Trade Among Agents” *Journal of Institutional and Theoretical Economics* 113 pp 1-41

⁴ Hu, Y. (2004) “Factors Influencing the Choice of Pricing Models in Online Advertising” Unpublished Doctoral Thesis, MIT Sloan School.

- H3a:* Project duration is a decreasing function of the IT use metrics: data entry (T_L) and networking (T_H).
- H3b:* Project multitasking is an increasing function of the IT use metrics: data entry (T_L) and networking (T_H).
- H4:* IT use (data entry (T_L) and networking (T_H)) is positively correlated with increased project completion and revenues.
- H5:* Increased revenues should be correlated with increased compensation.
- H6:* Monetary compensation should increase more with effort on more-observable T_H than on less observable T_L .
- H7:* Output and compensation will be an increasing function of the quality of a worker's communication network and the skills of his neighbors.

We explored the relationship of IT to project duration and multitasking, as stated by H3a and H3b. While it is presumed that IT use will speed up information work, our data suggest that the productivity effects are more complex than that.

Our analysis shows that not only is IT associated with increased output, but we also gain some insight into the mechanism by which it works. The estimates imply that IT is not used so much to speed up work as it is to increase the number of projects a recruiter handles at a given time. The slight increase of the average project duration for heavy IT users may reflect a willingness to dip further down into marginal projects (assuming faster projects are the first to be selected) or real bottlenecks in the recruiters' time – even with email and databases, there is still a need for a certain amount of real-time conversation with candidates and clients.

Our data also allowed us to study the compensation systems of the recruiters. This is a setting where the classic principal-agent model might be expected to fit fairly well, and the data suggest that it does. A significant fraction of the pay that the executive recruiters earn from their employers is explicitly linked to the revenue they generate. This reflects a job design that leads to a relatively high observable output: recruiters work on specific projects and the successes or failures of those projects, and the associated earnings, are easy monitor.

Consistent with H5, we find that approximately 1/3 of new billings are paid to employees who are responsible for generating those revenues. This provides very high powered incentives.

The evidence for H6 is also consistent with principal-agent theory but contains a modest surprise. Both uses of IT – email contacts and

database skill – are correlated with greater project completion rates and revenues. However, only email contacts, which by definition involve interactions with other people and are thus more observable, are correlated with greater compensation.

Conclusion

Our goal in this research was to model and measure the productivity of information workers at the task level, and specifically the role of IT use. We did this by developing new data gathering tools and collecting several types of new data, all in the context of a specific and relatively measurable group of information workers: executive recruiters. We found that our measures of IT use were significantly correlated with output at several levels: final revenue, completed projects and intermediate measures like number of projects managed simultaneously. At the same time, by peering into the black box of production at these firms, we found that some of the effects of IT can be counterintuitive: greater IT use does not seem to speed up task completion. On the contrary, it is correlated with greater duration time for projects, although the increase in multitasking more than offset this effect in terms of completed projects per year. The ability to multitask projects is highly significant and its effect, however, appears slightly paradoxical. Individuals who multitask more complete more work over the course of a year, however, take *longer* to complete their projects.

Our data also allow us to look more closely at the way compensation is tied to output and other factors. We found a very straightforward revenue sharing effect, with an employee earning about 1/3 of the additional revenues that he or she brings to the firm each year. We also found that relatively observable activities like email interactions with colleagues and others were correlated with both revenue generation and compensation. Meanwhile, less observable activities like database skill, while apparently valuable to the firm, are not associated with increased compensation.

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